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## THE DERIVATION AND SIGNIFICANCE OF CERTAIN SUPERNUMERARY MUSCLES OF THE PECTORAL REGION. By GEO. S. HUNTINGTON, M.D., *Professor of Anatomy, Columbia University, New York.* (PLATES I.-XIV.)

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THE primate pectoral region offers peculiar conditions both as regards the ontogeny of the pectoral muscles and the development of the ventral thoracic wall. As the direct result of these conditions a number of supernumerary muscles are encountered in this region, united into a correlated morphological group by their derivation from the plane of the pectoralis major and by the common etiological factors responsible for their production.

These variations present very definite and uniform structural characters, and, while some belong to the rarer muscular anomalies of this region, others, as the sternalis, occur more frequently, and in a remarkably constant percentage of the subjects examined. Abundant records of muscular variations in the pectoral group are scattered through the anatomical periodicals. The sternalis in particular has attracted widespread attention by reason of its peculiar morphological position, and has produced a literature of its own. Modern phylogenetic and embryological investigations have largely enhanced our knowledge of the developmental causes active in the production of departures from the normal myological type of this region, and it hence seems advisable to subject the entire group to a general revision with regard to the mutual relationship of the individual members and their derivation.

The variant muscles here considered are united into a homogenetic group by their common origin from the general muscular plane of the pectoralis. Within the limits of this group, however, certain members appear as muscular integers of reversional significance, in the broader sense presently to be defined, reproducing myological conditions which, while abnormal for the primate type, occur as normal constituents of the pectoral mass in some of the lower mammalian orders. Other variants belonging to this group, on the contrary, do not possess such reversional significance, and appear either as purely fortuitous variations, or as the result of peculiar mechanical and developmental causes, which, by disturbing the normal type of development of the primate pectoral musculature, lead to the production of a series of atypical and supernumerary pectoral muscles.

Thus the *tensor semi-vaginæ articulationis humero-scapularis* (Gruber) reproduces accurately the intermediate pectoralis (*M. sterno-humeralis*) found in certain of the lower mammalia, as in *Cercoleptes* (cf. *infra*, p. 8).

The constant and uniform structural character of this variation in all of the observed instances would alone suggest that it represents a myological type, abnormal as an element of the primate pectoral group, but forming a normal constituent of the pectoralis complex in certain of the specialised types assumed in other mammalian orders.

In the case of certain of the other variants here considered no such homologous muscles are found among the lower mammalian orders.

Both of these morphological subdivisions of the group owe their production primarily to identical etiological factors, resulting in a disturbance of the normal processes of pectoral muscular development.

In the case of the reversional variations this atypical development has occurred along definite channels, leading in other mammalian types to the inclusion in the pectoralis group, as normal constituents of the same, of muscular integers strictly homologous with the human variants. The abnormal human muscle has, so to speak, followed in its development lines of structural stability, which have been adopted in the differentia-

tion from the common antecedent mammalian type of the homologous pectoral segments normally encountered in certain mammalian orders below the primates. These variations may therefore be regarded broadly as reversional, in the sense presently to be more closely defined.

On the other hand, the fortuitous variations belonging to this general group do not represent structures normally found in the musculature of the mammalian series.

Topographically, according to the position occupied by the variant in reference to the plane of the pectoralis major, the entire group may be subdivided as follows:—

A. DEEP SUPERNUMERARY MUSCLES, situated in the interval between the pectoralis major and minor:—

1. *Tensor semi-vaginæ articulationis humero-scapularis* (Gruber).
2. *M. chondro-coracoideus ventralis* (*Pectoralis minimus*).
3. Some forms of the *M. præ-clavicularis*.

B. SUPERNUMERARY MUSCLES, placed superficially to the pectoralis major:—

1. *M. sternalis*.
2. *M. infra-clavicularis*.

In attempting to define the derivation and significance of these variations, and to establish their mutual relationship, the following factors deserve consideration:—

1. The share taken by atypical cleavage of the primitive pectoral mass into the ecto-pectoral (P. major) and ento-pectoral (P. minor and subclavius) in the production of supernumerary intermediate pectoral muscles.

2. The relation between the variant muscles and coexisting deficiencies in the sheet of the pectoralis major, especially conditions indicating that the variant represents a portion of the normal muscle atypically displaced.

3. The peculiar type of development followed by the pectoral group, as determined by Mall<sup>1</sup> and Lewis,<sup>2</sup> together with the

<sup>1</sup> F. J. Mall, "The Development of the Ventral Abdominal Walls in Man," *Journal of Morphology*, vol. xiv., No. 2, 1898.

<sup>2</sup> W. H. Lewis, "Observations on the Pectoralis major in Man," *Johns Hopkins Hospital Bulletin*, vol. xii., Nos. 121, 122, 123, April, May, June 1901.

development of the sternal bars and their fusion in the formation of the ventral thoracic wall.

4. The occurrence of muscular homologues in mammalian orders other than that of the primates.

5. The possible significance of some supernumerary muscles and superficial pectoral slips as persistent remnants of the thoraco-humeral panniculus, particularly in cases of combination with other aberrant pectoral muscles of undoubted pannicular derivation.

6. The innervation of the variants.

We may consider in the first place the structural details of the individual muscles, and then examine them in reference to the etiological factors above cited.

#### A. DEEP SUPERNUMERARY MUSCLES, occupying the ecto-ento-pectoral interval :—

1. *M. tensor semi-vaginae articulationis humero-scapularis* (Gruber).

It is necessary, on the ground of priority, to retain this somewhat cumbersome nomenclature, although the definition of the aberrant as *M. sterno-humeralis*, or *sterno-chondro-humeralis*, would in many respects be preferable.

In its typical development this supernumerary muscle, situated between pectoralis major and minor, forms a strong, flat fasciculus, arising from the first or second costal cartilage, or from both, and from the lateral margin and ventral surface of the sternum. The muscle traverses the clavi-pectoral space laterad, passing caudad of the subclavius and coracoid process. It lies upon the terminal portion of the pectoralis minor, the fasciculi intersecting the course of those in the latter muscle at an acute angle, and upon the combined origin of the coracobrachialis and short head of the biceps. It then expands into a strong triangular tendon, which continues beneath the ventral margin of the deltoid and joins the deep layer of the deltoid fascia, thus gaining an indirect attachment to the lateral humeral ridge and tuberosity.

#### *History of the muscle :—*

According to Macalister,<sup>1</sup> the muscle was first observed by

<sup>1</sup> "On Muscular Variations in Human Anatomy," *Trans. Royal Irish Academy*, vol. xxv., pt. i., p. 49, Dublin, 1872.



Gantzer. Wenzel Gruber<sup>1</sup> described it more fully under the name of *M. tensor semi-vaginæ articulationis humero-scapularis* as an elongated triangular or rectangular muscle, 16–19 cm. long, and varying from 3 to 14 mm. in width, occupying the interval between pectoralis major and minor, and included in a special sheath of the coraco-costal fascia. Gruber found the muscle in two male bodies, once bilateral, once confined to the right side. In these cases the muscle arose from the first or second costal cartilages, or from both, and from the adjacent portions of the manubrium and body of the sternum, crossed the pectoralis minor below the coracoid process, and continued over the united coraco-brachialis and biceps, expanding into a membranous tendon which radiated into the deep layer of the deltoid fascia, the cephalic fibres approaching those of the coraco-acromial ligament, while the caudal fibres became lost on the surgical neck of the humerus and the lateral bicipital ridge, after crossing superficially the ascending fibres from the tendon of the pectoralis major. No reference is made in the description to any coexisting deficiency in the sheet of the pectoralis major, and in the accompanying illustration<sup>2</sup> this muscle has been entirely removed.

Subsequently the same observer<sup>3</sup> reported an additional instance of the muscle in a subject with deficient radius.

Testut<sup>4</sup> quotes a case described by Pye-Smith, Howse and Colley in the *Guy's Hospital Reports*, 1870.

Macalister<sup>5</sup> found the muscle on the left side in a female chimpanzee, arising from the cartilages of the first and second ribs.

I am able to report four additional uncomplicated instances of the variation in the human subject, in one of which it occurred on both sides, and a fifth example in which the variant muscle was combined with a *M. sterno-chondro-coracoideus ventralis*.

The recorded cases of the muscle, described with sufficient

<sup>1</sup> "Die supernumeraeren Brustmuskeln des Menschen," *Mém. de l'Acad. Imp. de St. Pétersbourg*, 1860, No. 2, tome iii., p. 10.

<sup>2</sup> *Loc. cit.* tab. ii. fig. 2.

<sup>3</sup> *Virchow's Archiv*, Bd. 40, p. 427.

<sup>4</sup> *Les anomalies musculaires chez l'homme*, Paris, 1884, p. 16.

<sup>5</sup> *Loc. cit.*, p. 49.

detail to ensure correct identification, may therefore be tabulated as follows:—

Observer.	Number of Cases.	
W. Gruber, . . . . .	3 Cases, 1 bilateral,	} In man.
Pye-Smith, Howse and Colley, . . . . .	1 Case,	
Huntington, . . . . .	4 Cases, 1 bilateral,	
	1 Case in combination with M. sterno-chondro-coracoideus,	
	In the Chimpanzee.	
Macalister, . . . . .	1 Case.	
Total—10 Cases, presenting 12 muscles.		

While this is not a large number of observations, yet the uniform and congruent structural type of the variant in all the recorded cases is very striking, and entitles it to recognition as an established and independent variation. Of the five examples reported at this meeting of the Association, each presents certain features bearing on the derivation and significance of the variant. They are hence described *in extenso*: the first four uncomplicated cases under this heading; the fifth, occurring in combination with the M. sterno-chondro-coracoideus, under the latter muscle.

1ST CASE (Pl. I.). Subject number 1215, 1902, male, U.S., white, æt. 46.

*Left side.*—The pectoralis major sheet is complete in the sterno-costal division of the muscle, but the interval between this and the clavicular portion is very distinct, and larger than is normally the case. After division and reflection of the clavicular pectoralis a slender muscular belly is exposed, ventrad of the normal subclavius and separated from the same by the clavi-pectoral fascia. The aberrant muscle arises from the cartilage and bone of the first rib, crosses laterad over the pectoralis minor and below the coracoid process, and expands by a broad triangular tendinous leaf into the subdeltoid fascia.

*Innervation.*—By a filament from the nerve of the clavicular portion entering the muscle along the cephalic border near the origin.

2ND CASE (Pl. II.). Subject number 706, 1900, male, Ireland, æt. 37.

*Right side.*—The sheet of the pectoralis major is deficient in part of the second and third intercostal spaces. This cleft is occupied by a muscular band, arising from the sternum at the mesial extremity of the third interchondral space and from the adjacent margins of the third and fourth cartilages. The aberrant muscle is inclined more obliquely than the cephalic portion of the pectoralis major, beneath which it

dips in proceeding laterad. It crosses the pectoralis minor near the insertion and expands into a triangular tendon-plate, which becomes continuous with the subdeltoid fascia.

*Innervation.*—Branch from nerve of pectoralis major, entering deep surface of muscle.

3RD CASE (Pl. III.). Subject number 1360, 1902, male, Germany, æt. 59.

Bilateral defect of pectoralis major, and corresponding bilateral M. tensor semivaginæ.

*A. Left side.*—A distinct cleft separates the clavicular from the sterno-costal portion of the pectoralis major, the former leaving the ventral surface of the clavicle bare in its mesial fourth.

The sterno-costal portion is again deficient in its cephalic part. A reduced manubrial segment, arising from the sterno-clavicular capsule, the first costal cartilage and the adjacent portion of the pre-sternum, is separated from a more extensive caudal portion by a distinct interval corresponding to the second chondro-sternal junction and parts of the first and second interchondral spaces. This caudal portion of the pectoralis major arises from the sternum and costal cartilages, from the third to the sixth inclusive. The supernumerary intermediate muscle arises, partly under cover of the manubrial portion of the pectoralis major, from the adjacent borders of the first and second costal cartilages and the corresponding margin of the pre-sternum. Proceeding laterad it expands into a broad tendinous lamina which fuses with the subdeltoid fascia.

*B. Right side.*—The sheet of the pectoralis major is deficient between the sterno-clavicular articulation and the third chondro-sternal junction. This interval is occupied by the variant intermediate muscle, which arises from the second and third cartilages and the lateral sternal border included between them, and is inserted into the subdeltoid fascia by a broad tendinous expansion. The aberrant muscle is somewhat larger and better developed than the one on the left side, but the two variants correspond closely in all their structural details.

*Innervation.*—Identical on both sides. A slender branch from the external anterior thoracic nerve enters the muscle near the cephalic border of the deep surface. On the right side a small filament from the same branch passes to the clavicular portion of the pectoralis major.

4TH CASE (Pl. IV.). Subject number 1180, 1902, male, U.S. negro, æt. 29.

Subject of unusual muscular development.

The pectoralis major forms a massive plane, the muscles of the two sides interdigitating by short tendinous fibres across the mid-sternal line.

*Right side.*—The cleft between the clavicular and sterno-costal divisions is complete and well-developed. On reflecting the pectoralis major a strong flat intermediate muscular band is found crossing the fibres of the pectoralis minor at an acute angle. The variant

muscle arises from the ventral surface of the second costal cartilage and the adjacent border of the sternum under cover of the manubrial fibres of the pectoralis major. Laterad its insertion is partly into the ventral lamella of the pectoralis tendon, fusing with the cephalic fibres of the sterno-costal portion, partly by the expansion of the cephalic fibres into a strong tendinous lamina which unites with the subdeltoid fascia.

*Innervation.*—By two slender twigs, entering the ventral aspect of the muscle and derived from the branch of the external anterior thoracic nerve to the sterno-costal portion of the pectoralis major.

*M. sterno-chondro-humeralis*, homologous with the above-described human variant, and occurring as a normal constituent of the pectoral complex in other mammalia.

Many of the lower mammalia possess, between the superficial pectoralis and the deeper layer, a well-defined, flat muscular band, which, as *M. sterno-chondro-humeralis*, extends between the sternum and several of the proximal costal cartilages and the lateral surface of the shaft of the humerus, in some forms expanding broadly toward the insertion. I have met this muscle, which corresponds in all essential features closely to the above-described human variant, especially well developed in many carnivora, although some artiodactyla, as *Dicotyles*, possess the element in its most typical form.

In Pl. V. the pectoral musculature of the mink, *Putorius vison*, is shown, with the deep and intermediate layers exposed on the right side by reflection of the ecto-pectoralis. In Pl. VI. a similar dissection of the pectoral muscles of *Cercoleptes caudivolvulus*, the kinkajou, is shown. In both of these forms the intermediate sterno-humeralis appears completely separate and distinct from both the superficial and deeper layers, as a discrete element of the pectoral musculature.

## 2. *M. sterno-chondro-coracoideus ventralis* (*Pectoralis minimus*).

Among the numerically large group of the præ-clavicular aberrant muscles, two general divisions may be distinguished, according to the probable derivation of the variant:—

A. Forms which represent primarily and directly traces of the reversional appearance of the sterno-chondro-scapularis, the antecedent type of the human and anthropoid subclavius, and which are hence associated with the latter muscle in the narrower sense.

*B.* Forms more directly referable to the plane of the pectoralis major, appearing as atypical segments of this muscle.

Of course both of these groups share the common primary derivation from the general pectoral muscular mass, since the subclavius, or its generalized primitive form, the sterno-chondro-scapularis, differentiates from the cephalic part of the deep or ento-pectoral layer, while the pectoralis major appears as the superficial or ecto-pectoral sheet of the pectoral muscular plane.

Still, as a matter of convenience, reference of the variant in any given case to one of the two groups above defined is permissible, thus associating the atypical muscle either with the deeper stratum of the subclavius or with the superficial pectoralis major.

The latter group is so closely related to the variations just described that it can properly be considered in direct connection with them. This becomes especially evident in instances such as the one shown in Pl. VII., where the sterno-chondro-humeral slip (tensor semivaginæ) occurs in combination with the M. sterno-chondro-coracoideus, associated with pronounced deficiency in the plane of the pectoralis major.

Subject number 133, 1898 (Pl. VII.), female, Ireland, æt. 42.

*Left side.*—Pectoralis major poorly developed, with deficiency of medial segment of clavicular portion, producing a wide clavi-manubrial interval. This space is occupied by a fusiform muscle, arising from the ventral extremity of the first rib and cartilage. Proceeding laterad the muscle divides into two fasciculi, of which one, overlying the normal subclavius, is inserted into the tip and adjacent portion of the medial margin of the coracoid process, close to the insertion of the pectoralis minor, while the other expands into a broad tendinous lamina which joins the subdeltoid aponeurosis.

*Innervation.*—A branch from the external thoracic nerve, passing mesad along the cephalic margin of the pectoralis minor, gives a filament to the lower muscle and continues on the deep surface of the sterno-chondro-coracoideus, penetrating the same a short distance from the origin.

This case evidently presents a combination of the tensor semivaginæ with the supernumerary pectoral muscle variously described as *pectoralis minimus*, *præ-clavicularis medialis*, *s. sterno-clavicularis anticus*,<sup>1</sup> *s. sterno-chondro-coracoideus ventralis*.

<sup>1</sup> W. Gruber, *Reichert's Archiv*, 1865, p. 714.

ANALYSIS OF THE FIVE CASES OF THE M. TENSOR  
SEMI-VAGINÆ HERE RECORDED.

A comparison of the observations comprised in the above series leads to the following conclusions regarding the derivation and significance of the aberrant muscle and its relations to cognate variations of the pectoral region :—

1. The supernumerary intermediate muscle is clearly a displaced segment of the normal pectoralis major, as determined

(a) By the innervation, which in all five of the cases was furnished either through independent filaments from the external anterior thoracic nerve, or by twigs entering the substance of the variant muscles from branches supplying the normal pectoralis major.

(b) By the coexisting deficiencies in the muscular sheet of the pectoralis major, the gap being evidently produced by diversion of some of the fibres normally entering into the composition of the muscle to form the variant structure. This character is uniformly present in all of the above-described instances, although not equally pronounced in all.

In general it will be noted that the abnormal deviation of part of the pectoralis major to form the aberrant muscle usually involves the cephalic (manubrial) segment of the sterno-costal division, the origin of the variant centering at the second chondro-sternal junction and extending thence, in varying degrees in the different examples, cephalad toward the first cartilage, caudad toward the third, and mesad to corresponding points along the lateral sternal border (Cases 1, 3 and 4).

More rarely the central portion of the sterno-costal division of the pectoralis major furnishes the aberrant muscle, as in the second case above described, where the pectoralis is deficient over part of the second and third spaces and the intermediate muscle arises lower than in the other instances, viz., from the third and fourth cartilages. In this case the relation of the variant to the parent layer of the pectoralis major and its congruence with the deficiency in the same is especially clear and evident. With the more commonly observed higher origin of the intermediate muscle, as in Cases 1 and 4 of above series, the deficiency of the pectoralis sheet may appear as an increased

development of the normal cleft between the clavicular and sterno-costal divisions of the muscle. The third instance above described is especially instructive in this respect. Here, with bilateral development of the abnormal muscle and high origin of the same, the deficiency in the pectoralis major appears on the right side as an enormously enlarged claviculo-sterno-costal interval, while on the left side an additional cleft in the sterno-costal division clearly betrays the source of the fibres diverted from their usual course to form the variant intermediate muscle.

2. In considering the etiology of the variation, the following conclusions appear justified:—

(a) It is apparent that the abnormal muscle develops in consequence of faulty processes in the normal cleavage of the common pro-pectoral mass into a superficial or ecto-pectoral, and a deeper or ento-pectoral plane.

Both ontogenetically, as shown by Lewis,<sup>1</sup> and phylogenetically, as presented in a former communication<sup>2</sup> to this Association by myself, the primate pectoral musculature appears first as a uniform mass, yielding by subsequent cleavage the ecto- and ento-pectoral layers. The former is in general confined in origin to the sternal region, and apparently favoured in its differentiation and subsequent development by the mechanical advantages derived from the firm connection with this fixed skeletal portion of the ventral thoracic wall. The latter furnishes, by further segmentation, in its own plane, a smaller cephalic element, the subclavius, or its more generalized representative, the sterno-chondro-scapularis, and a larger caudal muscle, the pectoralis minor and abdominalis. In this primitive disposition the abdominal portion of the pectoralis at first appears as a caudal prolongation of the deeper ento-pectoral layer, coming into view beyond the caudal margin of the ecto-pectoralis, or pectoralis major *sensu stricto*, but associated with the pectoralis minor at the insertion.

Subsequently the abdominal pectoral differentiates from the

<sup>1</sup> *Loc. cit.*

<sup>2</sup> G. S. Huntington, "Present Problems of Myological Research, and the Significance and Classification of Muscular Variations," *Amer. Journal of Anatomy*, vol. xi., No. 2, pp. 157-175; 1903.

latter muscle, and this separation is further accentuated in man and the anthropoid apes by migration of the deep pectoralis minor insertion from the humerus cephalad to the coracoid process.

(b) In most of the lower primates the pectoralis minor retains the primitive humeral insertion in common with the pectoralis abdominalis and the axillary arch, when the latter structure is present, as a more or less distinctly specialized derivative from the thoraco-humeral panniculus, as is the case in the vast majority of the species composing the order below the group of the anthropoidea. It is only when these latter forms are reached that we begin to encounter typically the divorce of the two pectoral layers at the insertion, and the migration cephalad of the pectoralis minor from humerus to shoulder girdle, while the abdominal pectoralis remains secondarily connected with the pectoralis major, as a constituent of the dorsal plane of the tendon of insertion. Even among the anthropoid apes this secondary position of the pectoralis minor has not reached the uniformity and stability which characterizes it in the human species, where the occasionally-observed partial or complete prolongation of the minor tendon beyond the coracoid constitutes one of the more exceptional reversional variations of this region. Thus, while the coracoid insertion of the pectoralis minor obtains very generally, with minor specific differences, in the three remaining species of the great anthropoid apes, the arrangement of the muscle is subject to considerable variation in the chimpanzee. In the specimens examined by Broca and Humphry, and in two examples of my own series, the pectoralis minor was inserted altogether into the lateral tuberosity of the humerus. Hepburn and Champneys describe the muscle as passing over the superior surface of the coracoid to the capsule of the shoulder joint, and in one example dissected by myself this condition was approached, the pectoralis minor being only in small part attached to the coracoid, the remainder, separated from the cephalic surface of the process by a bursa, continuing into the shoulder capsule, closely associated with the supra-spinatus tendon. Alix and Gratiolet have previously described this divided insertion into capsule and coracoid in the chimpanzee. Finally Wilder reports a very significant



example of this animal, in which the pectoralis minor insertion was humeral on the right, but into the coracoid process on the left side.

(c) It is reasonable to assume that the production of the variant muscle here considered depends upon the individual development of a fault in the cleavage of the common pectoral mass, by reason of which a portion of the primitive common muscle, normally destined for the pectoralis major, and more or less coincident with the same along the line of origin, becomes diverted from this original purpose and follows the lead of the pectoralis minor in shifting the insertion from the humerus toward the shoulder girdle. In the majority of the cases the displaced segment of the pectoralis major does not reach the coracoid process, but results in the production of a slip intermediate in position and insertion between the typical major and minor, viz. the *tensor semi-vaginæ* of Gruber and of the series here described, with indirect humeral attachment by expansion into subdeltoid aponeurosis (Cases 1, 2 and 3 of above series). In the fourth case above reported a striking example is offered of a well-developed intermediate muscle still incompletely differentiated at the insertion from the remainder of the pectoralis major, but tending in its cephalic portion to assume the independent fascial insertion characteristic of the typical tensor semivaginæ. This case, therefore, represents an early and still incomplete stage in the differentiation of the variant from the parent layer of the pectoralis major. On the other hand, in the instance above described, in which the tensor occurs in combination with the chondro-coracoideus-ventralis (Pl. VII.), the aberrant muscle is seen in its most advanced stage, the association with the insertion of the ento-pectoral plane being sufficiently close to lead to the production of a twin muscle, one segment representing the typical tensor semi-vaginæ, with subdeltoid fascial insertion and indirect humeral attachment, while the other, in direct combination with the normal pectoralis minor, reaches the coracoid process as M. chondro-coracoideus ventralis.

## SUMMARY OF CONCLUSIONS BASED ON THE RECORDED OBSERVATIONS OF THE TENSOR SEMI-VAGINÆ.

### I. DERIVATION.

Sheet of pectoralis major, as evidenced by

- (a) The innervation (anterior thoracic nerves).
- (b) The coexisting and corresponding deficiency in the plane of the pectoralis major.

### II. ETIOLOGY.

Atypical cleavage of primitive pectoral muscular mass, a portion normally belonging to the system of the pectoralis major being partly diverted to the deeper ento-pectoral plane and following the lead of the latter in shifting the insertion cephalad toward the shoulder girdle.

#### A. *Incomplete Type* (Pl. IV.).

Insertion still largely associated with that of the normal pectoralis major, but partly continued into the subdeltoid aponeurosis.

#### B. *Complete Type* (Pls. I., II. and III.).

Insertion entirely into the subdeltoid fascia, intermediate between the attachments of the normal pectoralis major and minor.

#### C. *Advanced Type* (Pl. VII.).

Insertion partly extended to the coracoid process, resulting in the formation of a composite variant, the typical tensor semi-vaginæ appearing in combination with the *M. chondro-coracoideus ventralis*.

### III. SIGNIFICANCE.

It is, of course, not advisable to reason concerning the morphological and physiological significance of these variations from the comparatively limited number of observations except along the most generalized lines. The following conclusions may, however, be fairly drawn:—

(a) The remarkably constant and uniform structural character of the recorded cases, both as regards the variant muscle itself and the innervation on the one hand, and the relation to adjacent muscular planes on the other, entitle it to recognition as an independent and well-established variation.

(b) This morphological value is further supported by the phylogenetic representatives of the human variant encountered as normal constituents of the pectoral complex in certain of the lower mammalia.

(c) We may define such variations as "reversional," or, as Eisler<sup>1</sup> proposes in the case of the sternalis, seek to justify their occurrence by saying that they "have become independent." After all, however, such statements convey little meaning as to the real purpose and significance of the aberrant structure. In the case of the muscle here under consideration we may, at least tentatively, advance a step further and dwell on the significance imparted to the structure by the evident analogy between the causes responsible for its production and the phylogenetic processes which have led, in primates, to the present morphological status of the elements composing the normal pectoral musculature. As above stated, both the differentiation of the individual segments and the migration of the pectoralis minor from humerus to shoulder girdle can be clearly followed in the primate series, man and the anthropoid apes being generally sharply differentiated by the coracoid attachment of the pectoralis minor from the remaining genera of the order, in which the muscle largely retains the primitive humeral insertion. It is possible that in case of the variant muscle here considered we are dealing with the individual expression of evolutionary processes at present operative in the ecto-pectoral plane, and strictly analogous to those which, during the phylogenetic development of the present normal anthropoid type, have led in the deeper ento-pectoral plane to the diversion of part of its component fibres, as pectoralis minor, from humerus to shoulder girdle. In this sense the occurrence of the tensor semivaginæ would be interpreted as a "progressive variation," constituting a myological condition at present attained by a very small number of individuals, but possibly destined to become more constant in future evolutionary periods, and ultimately to appear as a normal component of the primate pectoral group.

<sup>1</sup> P. Eisler, "Der Musculus Sternalis, seine Ursache, und Entstehung, nebst Bemerkungen ueber die Beziehungen zwischen Nerv und Muskel," *Zeitschrift für Morphologie und Anthropologie*, Bd. III., Heft 1, 1901.

Again, in view of the transitional stage between the typical tensor semi-vaginæ and the præ-clavicular group of muscular variants, as illustrated in Pl. VII., it is possible to regard the former muscle as expressing one of the phylogenetic steps which have led to the establishment of the latter, *i.e.* to consider the tensor, so to speak, as representing arrest of development, or an intermediate stage, in the production of the præ-clavicular type of supernumerary pectoral muscle, especially of the sub-varieties of the ventral sterno-chondro-coracoid or sterno-clavicular forms. It is proper to recall in this connection that the various types composing the præ-clavicular group of variants are incomparably more frequent in occurrence than the tensor semivaginæ, and that the isolated instance of the latter muscle's occurrence in the anthropoid apes was recorded by Macalister in the chimpanzee, a form which, as above stated, has not yet attained a stable equilibrium in the coracoid attachment of the pectoralis minor, and hence may be assumed to offer a greater tendency to the production of atypical muscular elements associated etiologically with this process of migration.

These facts would speak, as far as they go, for the opposite interpretation of the muscle's significance, and would place the same in the category of "reversional variations" in the broader sense. This view, to which, considering all the available data, my own judgment inclines, would not regard the human tensor in any sense as representing a former component of the primitive primate pectoral musculature, and perpetuated as a normal element in some of the lower mammalia, as in the forms above described. The phylogenetic history of the primate pectoral mass is capable of complete and clear reconstruction, as previously shown,<sup>1</sup> and entirely contra-indicates such an assumption. The occurrence of a homologue in lower mammalia, morphologically equivalent to the human tensor, represents a specialization of the pectoral musculature in these forms and a wide departure from the primitive simple conditions which we may assume characterized the common primate type. Possibly, as above defined, such specialization indicates lines of election or of least resistance in the development of complicated components from a generalized mammalian pectoral type, and in that broad

<sup>1</sup> Huntington, *loc. cit.*

sense brings the normal carnivore or artiodactyle sterno-humeralis into relation with the variant primate tensor. A closer phylogenetic connection between the two is, I think, excluded by the recorded facts. On the other hand, the aberrant human muscle possesses a broad reversional significance if we regard it, not as repeating an extinct component of the primate pectoral adaptation, but as representing results of faulty or exaggerated processes which in their normal scope have led, during the phylogenetic evolution of the present primate type, to the establishment of the regular component elements.

The fact that the subclavius is undoubtedly a product of further segmentation in the deeper or ento-pectoral plane is responsible for a large number and variety of aberrant muscular slips in the præ-clavicular region, and more extensive irregularities in the normal processes of cleavage and segmentation may very fairly be regarded as capable of producing disturbances in the adjacent ecto-pectoral plane of the pectoralis major, thus bringing the tensor into indirect genetic relation with the præ-clavicular group, to be presently considered in this connection. The muscle, therefore, represents an atypical deviation of part of the pectoralis major, possibly as the direct result of faulty cleavage in the separation of the deeper ento-pectoral plane from the superficial layer, such atypically displaced fibres of the pectoralis major tending in their insertion toward the type presented by the pectoralis minor, and sharing to a certain extent in the migration of the latter toward or to the pectoral girdle.

This interpretation appears to me sustained by a comprehensive valuation of all the known facts. The limited number of actual observations, and the purely speculative character of our assumptions regarding the physiological and morphological factors charged with the production of what we have tentatively come to define as "progressive" variations, contra-indicate the inclusion, even provisionally, of the tensor in this doubtful class.

3. *M. sterno-clavicularis* (*Præ-clavicularis medialis*) (Pl. VIII. figs. 1 and 2).

Certain of the variant præ-clavicular supernumerary muscles evidently belong to the morphological group here considered.

In the instance shown in Pl. VIII. figs. 1 and 2 the following conditions were noted:—

#### DESCRIPTION OF CASE:—

Fœtus near term, male, presenting numerous congenital malformations—viz., exstrophy of the bladder, malformation of the external genitals, imperforate urethra, spina bifida, club feet and hands.

*Pectoral regions.*—The manubrial portions of the pectorales majores are confluent by a broad tendinous band across the ventral midline, without attachment to the underlying sternum. The clavicular portions of both muscles are divided into a broader lateral part, closely applied to the ventral border of the deltoid, and a narrower medial slip, arising from the sternal end of the clavicle and the sterno-clavicular articulation, laterad of the sternal attachment of the sterno-cleido-mastoid. These divisions of the clavicular head of the pectoralis major are separated by a broad triangular interval in which portions of two præ-clavicular supernumerary muscles appear, arranged nearly symmetrically on both sides (Pl. VIII. fig. 1). The narrow medial clavicular slip is separated from the confluent manubrial portions of the sterno-costal head on each side by a distinct cleft. On the right side the cephalic fibres of the manubrial portion of the pectoralis major pass directly beneath the narrow medial clavicular slip, diverging at an acute angle from the rest of the muscle, and form the caudal one of the two variant præ-clavicular muscles (sterno-scapularis) seen in Pl. VIII. fig. 1, partially exposed by the deficiency in the clavicular portion of the pectoralis major. On the left side the same two præ-clavicular muscles are present, but there is no direct continuity with the manubrial fibres of the pectoralis major, which pass directly into the main mass of the muscle toward the humeral insertion. On reflecting the pectoralis major and clavicular deltoid on the right side, and after division and upward displacement of the clavicle near the acromial extremity (Pl. VIII. fig. 2), the præ-clavicular muscles show the following arrangement:—

1. *M. sterno-clavicularis anticus*.

A bundle of well-developed muscular fibres arises from the manubrium, close to the clavicular notch, and extends parallel with the clavicle laterad to its insertion into the ventral surface of the bone a little beyond the middle.

2. *M. sterno-scapularis* (var. *sterno-acromialis*).

Caudad of the preceding muscle, and entirely distinct from it, the cephalic fibres of the confluent manubrial segment of the pectoralis major turn cephalo-laterad beneath the narrow medial clavicular slip and continue as a fusiform muscle, caudad and under cover of the clavicle, beyond the insertion of the sterno-clavicularis, and across the cephalic surface of the coracoid, terminating in a slender tendon which is inserted with slight expansion into the medial border of the acromion, dorsad of the acromio-clavicular facet.

On the left side the same arrangement obtains, except that the sterno-scapularis arises directly from the sternum and is not continuous with the confluent manubrial portions of the greater pectoral muscles. Both muscles are apparently innervated by a common branch, which passes around the caudal margin of the sterno-scapularis to their deep surface. This nerve can be traced back to one of the anterior thoracic branches entering the deep surface of the pectoralis major above the cephalic border of the pectoralis minor. The normal subclavius muscle is absent on both sides. The variation just described suggests the following considerations:—

1. As in case of the two preceding variant muscles, viz., the *tensor semi-vaginae* and *chondro-coracoideus ventralis*, the abnormal conditions are associated with faulty development of the pectoralis major and deficiency in its muscular plane, involving, however, in this instance the clavicular and manubrial heads of the muscle, whereas in the aberrant types previously considered the sterno-costal portion was atypically constructed and responsible for the production of the variation.

2. The two distinct abnormal muscles present in this case may be regarded as bearing the following relation to the pectoralis plane:—

(a) The sterno-clavicularis represents atypically displaced fibres of the deficient central portion of the clavicular head.

(b) The confluent manubrial portions of the two pectorales yield, on the right side directly, the second variant præ-clavicular muscle, which, as M. sterno-scapularis, replaces the absent subclavius, and represents the generalized mammalian type of this muscle (M. sterno-chondro-scapularis). Normally the primate subclavius, as previously shown,<sup>1</sup> appears as a segmentation derivative of the deep or ento-pectoral plane. The direct connection of its representative in this instance as sterno-scapularis with the superficial or ecto-pectoral plane of the pectoralis major suggests atypical development of the latter as the etiological factor responsible for the abnormal condition. The normal cleavage of the cephalic portion of the common pectoral mass into a deep stratum, yielding, by segmentation from the adjacent element of the pectoralis minor, the subclavian or sterno-scapular segment, and the superficial layer of the clavicular and manubrial pectoralis major has not occurred, possibly in consequence of the failure of the manubrial segment to gain the normal firm connection with the sternum. The resulting disarrangement of the pectoralis major in this region is manifested by the deficiency of the clavicular portion and by the deviation of part of the fibres normally composing the same to form the aberrant sterno-clavicularis, while the deeper layer, which should supply the typical primate subclavius, reverts in an incompletely segmented form, on the right side still directly continuous with the pectoralis major, to the generalized mammalian type of the subclavius, viz., the sterno-(chondro)-scapularis. In other words we are dealing here with another manifestation of the results produced by disturbances in the normal processes of cleavage in the pro-pectoral mass. In the case of the *Tensor semi-vaginæ* and the *sterno-chondro-coracoideus* previously considered, these disturbances involved the central (sterno-costal) division of the pectoralis major, and the muscular elements subtracted from the same formed the variant intermediate slips. These two muscles hence represent in a broad sense aberrations of development in the area of cleavage leading

<sup>1</sup> Huntington, *loc. cit.*, p. 70.



normally to the complete and typical separation of the sterno-costal division of the pectoralis major from the pectoralis minor. The two aberrant præ-clavicular muscles, on the other hand, appear as the results of the same general atypical processes transferred to the region of normal differentiation of the superficial clavicular and manubrial portions of the pectoralis major from the deeper segment destined to form the sterno-chondro-scapularis, or its reduced representative in primates, the subclavius.

A very interesting example of similar conditions in the pectoral region was reported in 1899 by Dr Thos. H. Bryce,<sup>1</sup> in which in a female subject, æt. 62, with normal pectoral muscles on the left side, the manubrial portion of the pectoralis major defaulted in large part on the right side, and there were present three variant pectoral muscles—viz., sternalis, sterno-clavicularis, and chondro-epitrochlearis. The sterno-clavicularis, supplied on its deep surface by a branch from the external anterior thoracic nerve, arose from the side of the manubrium and by tendinous fibres from the second costal cartilage, the outer part of the tendinous origin being directly continuous with the upper tendon of the sternalis.

Comparison of the figure and description given by Dr Bryce with the instance here reported reveals a remarkable congruence in the disposition of the pectoralis and of the præ-clavicular aberrant muscles in both cases. There can be no question as to the complete correspondence between the single large sterno-clavicularis of Dr Bryce's observation and the double variation of the present case, divided into sterno-clavicularis and sterno-scapularis. The same manubrial slip crossing the præ-clavicular muscle to join the main sterno-costal division of the pectoralis major is present in both, as is also the wide interspace between this manubrial slip and the clavicular head, and while in Dr Bryce's case the sterno-clavicularis becomes in part continuous with the sternalis, the second aberrant muscle of our example—the sterno-scapularis—joins on the right side directly the confluent manubrial portion of the pectoralis major, a fact of much meaning in reference to the pectoral character of the sternalis (*vide infra*).

<sup>1</sup> *Journ. Anat. and Phys.*, vol. xxxiv., pt. i., pp. 74-78.

Dr Bryce concludes in respect to the sterno-clavicularis of his case that "it evidently represents a portion of the deep lamella of the pectoral sheet arising from the manubrium, and it is significant that when present, either in its single or double form (inter-clavicularis anticus digastricus), there is frequently a defect in the pectoralis major."

He also quotes a similar instance reported by Dr Dwight.<sup>1</sup>

Further, in a case reported by Dr Stoker and quoted by Macalister,<sup>2</sup> the pectoralis major was absent. Two similar instances are described by Gruber,<sup>3</sup> in which the clavicular portion of the pectoralis major was deficient on the side presenting the præ-clavicularis medialis. I am in entire accord with Dr Bryce when he sums up his view concerning the sterno-clavicularis by saying that "it is therefore, in virtue of its position, a 'deep manubrial slip,' and, in virtue of its innervation, belongs to the same category as the pectoralis minimus and other slips derived from the same point. They may all be regarded as different forms of the part of the deep lamella of the pectoral sheet, usually suppressed in man, arising from the manubrium and supplied by the external anterior thoracic nerve."

I would amplify this excellent *résumé* of the morphological position of the sterno-clavicularis and pectoralis minimus by including in the same group the sterno-costal variants, tensor semi-vaginæ and transitional forms between it and the sterno-coracoideus, as well as the group of aberrant types involving, as various forms of the sterno-chondro-scapularis, the region of the normal subclavius.

As regards the etiological factors responsible for the production of the variations, I have above expressed the view that we are not dealing here with reversional structures in the strict sense, "usually suppressed in man," but with the results of very definite and limited developmental and phylogenetic influences peculiar to the pectoral region.

<sup>1</sup> *Journ. Anat. and Phys.*, vol. xxii., 1888, p. 98.

<sup>2</sup> *Loc. cit.*, p. 50.

<sup>3</sup> *Reichert's Archiv*, 1865, p. 708.

## SUMMARY OF CONCLUSIONS REGARDING THE THREE TYPES OF SUPERNUMERARY MUSCLES FORMING THE DEEP GROUP.

It is not difficult to correlate the morphological conditions offered by the three supernumerary muscles here considered and to recognize them as members of a continuous series whose individual position and relation to the entire pectoral complex may be schematically represented in Pl. IX.

The following conclusions regarding the group as a whole appear justified :—

1. The individual muscles share a common derivation from the pectoralis plane. This is established both by the constant innervation by the anterior thoracic nerves and by the nearly uniform coexistence of distinct deficiencies in the plane of the pectoralis major.

2. The etiology of the variants depends upon abnormal processes in the cleavage of the pectoral mass, disturbing the normal differentiation of the same into pectoralis major, pectoralis minor, and subclavius, and leading to the production of supernumerary accessory slips of greater or lesser extent.

3. The process of cleavage in these cases, while atypical for the primate disposition of the pectoral complex, may follow lines which are normal in the differentiation of the pectoral components in other mammalian orders. Hence some of the aberrant human muscles are morphologically homologous with intermediate pectoral elements normally found in some of the lower mammalia.

4. It is fair to assume that departures from the normal type of cleavage are favoured

(a) By the tendency to reversion, to a greater or less degree, to the primitive undifferentiated and unsegmented pectoral mass which, both phylogenetically in the primate order, and ontogenetically in the human embryo, forms the starting-point for the subsequent differentiation into the typical components.

(b) By the embryonic migration of the pro-pectoral mass from the cervical to the sterno-costal region, which affords opportunities for faulty completion of the secondary attachment to the ventral thoracic wall and shoulder girdle, and may thus give rise to the development of atypical muscles (*vide infra, Sternalis*).

5. These factors, operating over localized areas of the pectoral mass, produce the following individual aberrant forms, according to the position of the part of the pectoralis sheet involved (Pl. IX.):—

*A. Central sterno-costal segment of pectoralis.*

1. Tensor semi-vaginæ or sterno-humeralis, still associated with pectoralis major at insertion (Pl. IV. and Pl. IX. 5).

2. Typical tensor semi-vaginæ or sterno-humeralis inserted into subdeltoid aponeurosis, and thus obtaining an indirect humeral attachment (Pls. I., II. and III.; Pl. IX. 5).

*B. Segment involved in the normal cleavage of pectoralis major and minor.*

1. Typical sterno-chondro-coracoideus ventralis, S. pectoralis minimus (Pl. IX. 3).

2. Sterno-scapularis (Pl. VIII. fig. 2; Pl. IX. 2).

(A large number of recorded observations of so-called "reduplications" of the subclavius belong to this group.)

*C. Intermediate pectoral segment between A and B.*

Combination forms of sterno-humeralis or tensor and sterno-chondro-coracoideus ventralis (Pl. VII. and Pl. IX. 4).

*D. Manubrial and clavicular segment.*

By reduction and further migration of insertion to clavicle is obtained the sterno- or sterno-chondro-clavicularis ventralis in its various sub-types (Pl. VIII. figs. 1 and 2; Pl. IX. 1).

**B. SUPERNUMERARY MUSCLES SUPERFICIAL TO THE PLANE OF THE PECTORALIS MAJOR.**

This group includes in or near the ventral midline of the thorax the well-known sternalis, and further laterad in the delto-pectoral space the occasional infra-clavicularis. A careful consideration of these pectoral variants warrants their union, as regards derivation and significance, with the deeper intermediate supernumerary muscles just discussed into a common morphological group. The superficial supernumerary muscles,

while differing from the deeper variants in their relation to the parent layer of the ecto-pectoralis, share with the latter the common derivation from this layer, and owe their production in part to the same etiological factors responsible for the development of the deeper muscles, in part to special conditions favouring atypical development on the superficial aspect of the pectoralis sheet.

## I. STERNALIS.

So much has been written concerning the structure, innervation and probable morphological significance of the sternalis, that further contributions to the literature of the muscle seem superfluous unless thereby some additional light can be thrown on the still problematical character of this frequent variation. This is especially the case since the publication of the very able and comprehensive paper on the muscle by P. Eisler<sup>1</sup> in 1901, in which the author deals fully and completely with the neurological problems involved and advances a novel view regarding the factors responsible for the production of the variation.

An attempt to define the morphological position of the sternalis will be facilitated by the preliminary consideration of the present status of our knowledge concerning the innervation of the muscle, and by a brief review of the more important theories which have been advanced in explanation of the derivation and significance of the variant.

### 1. INNERVATION OF THE STERNALIS.

We owe our first definite knowledge concerning the nerve supply of the sternalis to the careful researches of Prof. Cunningham, who first laid stress on the importance of this criterion in the determination of muscular homologies, and to Prof. Shepherd, who has recorded the nerve supply in an interesting series of cases occurring chiefly in ancephalous monsters. Prof. Bardeleben of Jena has likewise contributed neurological data, and more recently Dr Christian,<sup>2</sup> in recording the nerve supply in two cases of sternalis observed by him,

<sup>1</sup> *Loc. cit.*

<sup>2</sup> *Bulletin of the Johns Hopkins Hospital*, vol. ix., Nos. 90-91, p. 235, Sept.-Oct. 1898.

tabulates a series of 27 muscles with determined innervation, showing the following results :—

	No. of Sternales.
Ventral branches of II.-IV. intercostal nerves alone,	14 muscles.
Ventral thoracic nerves alone, . . . . .	10 „
Ventral thoracic and intercostal nerves combined, . . . . .	3 „
	—
Total, . . . . .	27 „

Since the publication of these earlier records the number of careful observations on the nerve-supply of the sternalis has greatly increased, and of late years the conviction has steadily gained ground that the sternalis is always innervated by the anterior thoracic nerves, and not by the intercostals, the reported instances to the contrary notwithstanding. While frequently *perforated* by ventral cutaneous intercostal branches, the motor-supply is to be traced to the anterior thoracic complex. Hence neurologically the sternalis belongs to the domain of the pectoralis.

Eisler, in the paper quoted, joins the constantly-growing number of morphologists who have, with the multiplication of neurological determinations after improved methods, experienced more and more doubt as to the validity of the recorded cases of sternales with intercostal innervation, either alone or in combination with a supply from the anterior thoracic nerves, and who have arrived at the conclusion that the muscle is uniformly supplied by the anterior thoracic nerves alone, and hence directly associated with the pectoralis musculature.

## 2. HYPOTHESES CONCERNING THE DERIVATION AND SIGNIFICANCE OF THE STERNALIS.

The main views heretofore advanced regarding the morphological position of the muscle may, for discussion and comparison, be briefly enunciated as follows :—

### *A. Pannicular derivation of the sternalis.*

This view, first presented by Turner<sup>1</sup> and adopted by a number of subsequent observers, regards the sternalis as

<sup>1</sup> *Journ. Anat. and Phys.*, vol. i., p. 247.

a reversional persistent remnant of the thoracic cuticular muscle.

*B. Ecto-pectoral derivation of the sternalis in the stricter sense.*

Cunningham<sup>1</sup> clearly defined the relation of the sternalis to the muscular sheet of the pectoralis major, and held the variant to be a displaced and rotated segment of the latter.

*C. Eisler's hypothesis.*

Eisler,<sup>2</sup> in echoing Cunningham's view as to the direct derivation of the sternalis from the pectoralis major, assumes a definite mechanical cause for the abnormal development of the pectoral sheet leading to the production of the variation, believing the same to be due to an atypical widening of the ventral portions of one or more intercostal spaces, such widening being possibly caused by hyperplasia of the thymus and by the large size of the heart. The frequency of the sternalis in ancephalic monsters (twelve times greater than in "normal" individuals) is, according to Eisler, primarily produced by the factors indicated, and further favoured in these cases by the constant and marked lordosis of the cranial segment of the vertebral column. Eisler purposes, in fact, to place the sternalis in a separate group of muscular variations composed of atypical myological structures which have "become independent." The examination of a sufficiently extensive series of the variation, in the light of the three hypotheses above outlined, will convince the observer that a certain proportion of the individual cases are structurally in accordance with one or the other of the two main views which have been expressed in regard to the derivation and significance of the muscle, *i.e.* they appear either to fulfil the conditions demanded by what we can term briefly Turner's pannicular hypothesis, or they correspond, as clearly displaced segments of the pectoralis major sheet, to the mechanical theory of the Cunningham-Eisler conception. Furthermore, a certain number of individual instances will occupy a position intermediate between these two groups, the variant partaking of the structural character of both, although usually inclining

<sup>1</sup> *Journ. Anat. and Phys.*, vol. xxii., p. 392.

<sup>2</sup> *Loc. cit.*

more to the one or the other. In other words a sufficiently comprehensive series of the variation will reveal the existence of the following types, which the muscle may assume in individual cases:—

A. Sternales, occurring usually as well-developed muscular bands, associated with disturbances in the typical development of the pectoralis major, and usually accompanied by more or less pronounced deficiency in the corresponding segment of the sterno-costal division of the muscle (Pl. X.).

B. Sternales characterized by the slender and delicate form of the aberrant muscle, varying in extent from a few scattered muscular fibres to a thin ribbon of pale muscular tissue overlying the pectoralis major, which appears fully developed and to all appearances normal in every respect. The terminal connections of the muscle in these cases are frequently fascial or aponeurotic, caudad the abdominal fascia or sheath of the rectus, cephalad the deep pectoral fascia, periosteum of the sternal midline, or sternal tendon of the sterno-cleido-mastoid.

As recently shown by Anthony,<sup>1</sup> it is possible to regard certain pre-pectoral fascial and fibrous bands as the metamorphosed and rudimentary representatives of the muscular sternaless belonging to this group.

C. Sternales which in general partake of the structure of the second group, but which present a more direct connection with the pectoralis major. This is usually indicated, not by a corresponding deficiency in the pectoralis sheet, as in Group A, but by the continuation of some of the sternalis fibres into the pectoralis, or by the origin of part of the superficial layer of the latter muscle from the cephalic tendinous prolongation of the sternalis. At times the element appears as a superficial lamina of the pectoralis, continued separate from the main muscle well toward the insertion, as in the ancephalic specimen shown in Pl. XI. fig 1.

No observer, in critically examining a series of this kind, will for a moment doubt the general congruence of the different examples and the morphological entity of the variant as a distinct anatomical structure, possessing a common fundamental

<sup>1</sup> M. R. Anthony, "Le muscle présternal ; ses formes fibreuses rudimentaires, leur fréquence chez l'homme et leur présence chez certain animaux," 11 fig., *Bull. de la Soc. d'Anthropol. de Paris*, 5 Livre, 1, 1900, pp. 486-509.



character, no matter what special features may induce the assignment of any individual case to one or the other of the general groups above defined. In other words, it would be impossible to hold that the different characters possessed by a selected series of individual instances of the muscle implied in any sense a fundamental difference in the derivation and significance. We are not dealing here with a number of structures morphologically differentiated by their origin and possessing merely a superficial resemblance to each other, but with a series of uniform derivation and significance, the individual members of which may, to a greater or less degree, present secondary differential characters. The sternalis is a muscular integer, and I am convinced that we can harmonize the apparently divergent phylogenetic and etiological views expressed concerning the history of the muscle by establishing a broader morphological basis for its derivation, which, according to the preponderance of secondary influences, may lead its development into one of several specific directions, resulting in the establishment of certain distinctive characters for the subdivisions of the muscle above enumerated. The fundamental basis for the morphological union of all the specific types assumed by the sternalis in individual cases must be sought in the ultimate derivation of the myological elements composing the variant from the pectoralis sheet. This final reference to the origin, clearly sustained by the innervation, is made the direct basis of the hypothesis advocated by Cunningham and Eisler. Furthermore, it is in entire accord with the pannicular theory of Turner, when the innervation of the thoraco-humeral skin-muscle and its relation to the superficial pectoral muscular sheet is correctly appreciated. With the acceptance of the general derivation of the sternalis from elements of the pectoral musculature, there remain the following points for consideration:—

1. The general etiological factors which lead to the remarkably constant percentage occurrence of the variation.
2. The striking numerical preponderance of the sternalis in the ancephalic foetus.
3. The causes which determine the secondary group-characters of the muscle.
4. The relation of the sternalis to cognate variations of the

pectoral region, and especially the determination of the significance of instances in which the sternalis appears in conjunction with other pectoral variants.

I believe we can best arrive at a solution of these questions by provisionally retaining the classification of the types presented by the sternalis as above given, and by examining the individual groups seriatim.

*Group A.*—Well-developed sternales, with coexisting deficiency in the plane of the pectoralis major.

These cases furnish an advantageous starting-point for the general consideration of the muscle, since they offer very evident conditions, which pave the way for the subsequent study of the more obscure instances included in Groups B and C.

In examples of this type, as shown in Pl. X., the abnormal muscle appears clearly in Cunningham's and Eisler's sense as an atypically developed and displaced segment of the sterno-costal pectoralis major, whose connections with adjacent structures, as the frequent union with the sternal head of the sternocleido-mastoid or the aponeurosis of the external oblique, are secondarily acquired and morphologically unimportant characters. As previously seen, similar displacements of pectoralis elements, involving portions of the deeper plane of the muscle, lead to the production of the supernumerary intermediate pectoral muscles considered in the first part of this communication. In these instances the derivation and significance of the aberrant sternalis are perfectly clear and evident, and it only remains to gain what light we can on the question of the causes responsible for the atypical pectoral development. There is much in Eisler's conception of the sternalis which, if borne out by further and more extensive observations, would fill important gaps, heretofore left vacant, in our knowledge of these causes.

His mechanical theory of the production of the variation offers a plausible explanation of the cases of sternalis with exceptional defect in the sheet of the pectoralis major, either in the ancephalic foetus or in adult subjects. Such cases do indeed correspond to the conception of an atypical development of the pectoralis with rotation or displacement of the muscle fibres involved in the disturbed area. I confess, however, that the atypical structure of the thoracic wall, and especially the ab-

normal widening of certain interchondral spaces, upon which Eisler lays stress as etiological factors of the first importance in the production of the variation, do not, as far as my present observations go, obtain, at least by no means uniformly. I have recently examined carefully the skeletal structures of the ventral thoracic wall in five instances of the sternalis occurring in adult subjects. Among these were two in which the muscle assumed the delicate ribbon form of Group B, and the example with extensive deficiency of the pectoralis major and strong muscular sternalis shown in Pl. X. In only one of the five instances—a case of superficial and slender sternalis—was a slight degree of asymmetry noticed. In the other four the thorax appeared perfectly normal, and the sternum and interchondral spaces of the subject shown in Pl. X. were remarkably regular and well formed (Pls. XII. and XIII.). In view of the frequency of asymmetrical development of sternum and costal cartilages in individuals who do not present any abnormality of the pectoral musculature, I am inclined to question the direct relation between thoracic asymmetry and the development of the sternalis. It is possible that we are dealing here rather with a coincidence than with an etiological element of moment. I am somewhat confirmed in this impression by the results of an examination of the ventral chest wall in eight ancephalic foetus which presented no trace of the sternalis. In three of these marked atypical structure of the costal cartilages and irregular formation of the interchondral spaces were found. In one of these the fourth left rib presented the bifid termination occasionally seen. I should judge that ancephaly is apparently a favouring factor in the development *both* of the sternalis and of irregular formation of the interchondral spaces, but that the muscle does not depend directly for its production upon the latter condition. They may both appear in the same individual, or the malformation of the thorax may occur without the development of the sternalis, or the muscle may be found overlying a thorax normal in configuration. This question, however, will require definite determination on the basis of a very much larger series of observations than are at my disposal at present. On the other hand, these instances of sternalis with well-marked deficiency in the pectoralis major present features which clearly

bring them into line with the muscular variants previously considered occupying the deeper layers of the pectoral complex. A comparison, for example, of the pectoral system of the two individuals shown in Pls. III. and X. will at once suggest the propriety of uniting them into a general group characterized by the correspondence of the abnormal development in the area of the pectoralis major, which has in the one case led to the production of the deep tensor semi-vaginæ, while in the other it has resulted in the appearance of the superficial sternalis. In both instances the derivation of the atypical segment is clearly indicated by the coexisting deficiency in the ecto-pectoral sheet.

We have previously characterized the deep supernumerary muscles of this region as products of atypical cleavage in the deeper strata of the pectoralis mass, resulting in departures from the normal type of myological evolution which in the human subject leads to the differentiation of the pectoralis major from the deeper layer composed cephalo-caudad of subclavius, pectoralis minor and pectoralis abdominalis.

In comparing the two examples referred to, the suggestion lies at hand that identical etiological forces have determined the disturbances of normal development, which in its final result furnishes us with two apparently entirely distinct muscular structures. In the one case these disturbing forces, operating in the deeper plane of the pectoralis mass, produce the tensor semi-vaginæ, or one of the group of allied intermediate muscles above considered. In the other the same forces, directed and perhaps specially modified by secondary etiological factors involving the superficial stratum of the pectoralis major, lead to the development of the sternalis as it appears in the group now under discussion.

If, therefore, based on the innervation and the coexisting deficiency of the pectoralis major sheet, we accept the common derivation of both the deep and superficial group of supernumerary pectoral muscles, we must seek further for the deciding causes producing this atypical development, and, moreover, consider what additional elements lead, on the one hand to the development of the atypical deep or intermediate series already discussed, and, on the other, to that of the superficial sternalis.

I have already expressed my belief that the deep group can be genetically considered as derived from the deeper lamina of the ecto-pectoral layer in consequence of faulty and incomplete cleavage in that portion of the embryonic pro-pectoral mass which is the site of the normal differentiation into the superficial element of the pectoralis major and the deeper layer comprising pectoralis abdominals, pectoralis minor and subclavius.

In the genesis of this group disturbances in and deviations from the normal embryonal process of *cleavage* or *differentiation* are primarily responsible for the development of the variant. I believe that we can ascribe the production of the sternalis to analogous disturbances in another part of the normal ontogenetic cycle which leads, when typically carried through, to the establishment of the pectoral relations as usually encountered, but which, by reason of the complex factors entering into the process, is prone to disturbances involving the superficial plane of the pectoralis and resulting in the development of the sternalis, as a part of the pectoral sheet deviated and rotated in Cunningham's sense to a position ventrad of the parent layer.

The three elements concerned in the ontogenetic history of the pectoral musculature, which must be considered together in their mutual relations in attempting to determine the etiology of aberrant pectoral muscles, are—

1. The cleavage of the entire mass into the superficial (ecto-pectoral, P. major) and the deep layer (entc-pectoral, including P. abdominalis, P. minor and subclavius).
2. The peculiar type of development of the pectoral muscles.
3. Certain stages in the development of the ventral thoracic wall.

As above stated, I am inclined to ascribe the deep or intermediate group of pectoral variants to disturbances in the first of the above embryonic elements, viz., the *cleavage* of the entire mass.

For the production of the sternalis I believe that we will have to reckon with the other two ontogenetic factors concerned:

1. *Development of the pectoral musculature.*—The researches

of Mall<sup>1</sup> and Lewis<sup>2</sup> have greatly augmented our knowledge of the embryonic details in the development of the trunk musculature. Lewis finds that the pectoralis major arises in common with the minor from a pre-muscle tissue located for the most part above the first rib. He examined by reconstruction and dissection embryos from 9–40 mm. The pro-pectoral mass is located chiefly in the neck, and lies at first in the region of its nerve-supply, receiving branches from the sixth, seventh and eighth cervical and first thoracic nerves, which proceed almost directly laterad with scarcely any caudal inclination. This mass gradually shifts caudad to the costal region, splitting into bundles during the process of migration. The clavicular portion is the first to segment from the common mass. Later the sterno-costal portion differentiates into the P. major and minor. During the migration the sterno-costal bundles overlap, so that the superficial fibres of each bundle descend farther than the deeper ones, possibly by reason of the latter acquiring an earlier attachment to skeletal points.

This ontogenetic migration of the pectoral muscle mass strongly suggests the possibility of finding in disturbances of the normal process the cause of the development of the superficial aberrant pectoral muscles, chiefly represented by the sternalis. Lewis, at the close of his very able paper, points out the etiological significance of his observations in reference to supernumerary pectoral muscles, and his suggestion appeals to me as the most satisfactory explanation of the conditions which *a priori* favour atypical muscular development in this region. If we seek for further contributory causes, it is proper to bear in mind the following facts:—

Lewis' observations have determined that in the pectoral migration the deeper planes are arrested earlier, while the superficial fibres continue to descend and thus come to overlap the deeper strata. The superficial portion of the pectoralis major is, therefore, longer in a condition of comparative independence of the skeletal points to which, in the normal progress

<sup>1</sup> F. J. Mall, "The Development of the Ventral Abdominal Walls in Man," *Jour. of Morphology*, vol. xiv., No. 2, 1898.

<sup>2</sup> W. H. Lewis, "Observations on the Pectoralis major Muscle in Man," *Johns Hopkins Hosp. Bull.*, vol. xii., Nos. 121, 122, 123, April, May, June 1901.

of development, it becomes attached, and more subject to the influence of abnormal connections, established with adjacent structures, perhaps prior to or during the earlier stages of migration. The frequent cephalic fusion of the sternalis with the sternal tendon of the sterno-cleido-mastoid is perhaps to be interpreted in this sense. In case of an abnormal connection of that kind in the earlier developmental stages, we are, I believe, confronted by one of the causes which will lead to rotation of part of the pectoral plane from the typical position assumed in normal development, and which will carry the affected segment, during the continued migratory descent of the main mass, into the atypical vertical position characteristic of the sternalis, preserving, at the same time, in many cases the evident abnormal connection, as with the sterno-cleido-mastoid, which, by establishing a fixed point of early attachment for portion of the muscle, primarily led to its deviation from the normal direction assumed by the remainder. The fact that the *superficial* portion of the pectoralis is embryologically the last part to become definitely fixed in the usual sterno-costal attachment offers a ready explanation of the pre-pectoral position of the sternalis.

2. In studying in detail an extensive series of sternales, a surprisingly large number of muscles present a peculiar and definite relation to the mid-sternal line. The muscular fibres in these cases are directed cephalo-mesad from the caudal origin and appear in well-marked instances inserted entirely along the vertical mid-sternal line, while in other cases a partial or complete sterno-mastoid connection also exists. These conditions are, for example, well seen in the two individuals shown in Pl. X. and Pl. XI. fig. 2, and, while by no means of uniform occurrence, they are found in a sufficiently large percentage of cases in such a definite and characteristic form as to warrant their consideration in estimating the secondary causes which we may reasonably hold responsible for disturbances in the normal ontogenetic process of pectoral descent, and the consequent production of variant muscles representing portions of the pectoralis atypically displaced during migration. In this sense the cephalic attachment of the sternalis to the mid-sternal line suggests the possibility that in shifting from the

primary cervical to the subsequent sterno-costal position, portions of the pectoralis sheet may become included in the closure of the sternal bars in the ventral midline, and thus obtain a cephalic fixed point, which, in the continued descent of the superficial portions to overlap the deeper bundles—as it normally occurs—causes a larger or smaller segment of the superficial pectoral plane to deviate into the vertical position, and yield in course of complete development the sternalis of the type under consideration. In some instances, as in the example shown in Pl. XI. fig. 2, the oblique parallelogram described by the muscle is very striking, with the fibres ascending obliquely cephalo-mesad and terminating along the sharply-defined vertical insertion into the mid-sternal line. The facts just considered seem to afford a reasonable explanation not only of the principal and secondary causes leading to the atypical development of part of the pectoralis major as the sternalis, but also to account for the variability in size, attachments, relation to the parent layer and coexisting deficiencies of the latter, as represented by the various individual types of the variant muscle. In other words the sternalis appears as the product of several developmental factors, diverted from their normal course and acting in conjunction—viz., primarily, the ontogenetic migration of the propectoral mass and the later fixation of the superficial fibres, as compared with the earlier attachment of the deeper plane; secondarily, the possibility of atypical connections established prior to or during the early stages of this migration with adjacent structures, as the sternomastoid; lastly, the possible inclusion of part of the pectoralis major in the closure of the mid-sternal cleft. The various specific characters exhibited by individual instances of the muscle will be determined by the amount of pectoral tissue involved and by the preponderance of one or the other of the secondary causes.

*Group B.*—Sternales appearing as delicate scattered fibres or thin muscular bundles, overlying a normal pectoralis major, without evident deficiency in the substance of the latter.

From the statements just made concerning the first group, it is quite evident that the muscles classified under this second head may fairly be interpreted, in reference to derivation, as segments of the pectoralis sheet in cases in which the rotated and



atypical displaced portion forms so small a part of the embryonic pectoral mass that its loss and diversion leaves no appreciable deficiency and produces no disturbance in the typical development of the main muscle. This is the most reasonable and evident interpretation of the special group of the variant here considered. Since this type of the sternalis has, however, furnished the basis of the "pannicular theory" of its derivation, it is well to consider the facts bearing on this interpretation in connection with the general discussion of this particular group.

It must be admitted that the structure of a certain number of sternales, belonging morphologically to this group, suggests at first sight that they represent abnormally persistent portions of the thoracic panniculus. Furthermore, the sternalis has been observed in conjunction and partial continuity with other aberrant pectoral slips of undoubted pannicular origin. These cases deserve special consideration. A marked example is shown in Pl. XI. fig. 2, presenting the following features:—

Female subject, æt. 43, Ireland.

1. Sternalis, confined to the right side, arises by a broad sheet of convergent aponeurotic fibres, continuous caudad with the aponeurosis of the external oblique over the rectus abdominis, corresponding to the level of the fifth costal cartilage. Mesally the fibres of origin continue with a curved course over the cephalic portion of the rectus to the xiphi-sternal junction, while the lateral border of the aponeurotic lamella continues directly into the origin of the second variant muscle, a well-marked pectoralis quartus. The sternalis measures 11·5 cm. in length and averages 2·75 cm. in width. It is inserted by short tendinous fibres into the ventral surface of the sternum opposite the second chondro-sternal junction. The cephalic fibres continue as a slender tendon—2 cm. in length—firmly attached in the mid-sternal line to the periosteum of the pre-sternum as far as the jugular notch, fusing with the mesal fibres of the sternal attachments of the two sterno-cleido-mastoid muscles, which meet in the middle line.

2. *Pectoralis quartus*, unilateral, confined to the right side, arises over the fifth right costo-chondral junction, the mesal fibres being directly continuous, as already stated, with the lateral margin of the origin of the sternalis, and not attached to the deeper parts, while the remainder of the muscle arises by short tendinous fibres from the fifth costal cartilage near its junction with the rib. The quartus, forming a flat band 18·5 cm. long, with an average width of 1 cm., continues laterad along the border of the pectoralis major, but entirely distinct from the same, across the axilla, to be inserted, together with the axillary arch, on the deep surface of the pectoralis major tendon.

3. *Axillary arch*.—Present on both sides.

On the right side it forms a muscular band, 5 cm. long and 0·75

cm. wide, which arises by a distinct tendinous intersection from the ventral surface of the latissimus dorsi, crosses the large vessels and nerves, and, joining the pectoralis quartus, is inserted with this muscle on the deep surface of the pectoralis major tendon.

On the left side the axillary arch, 7 cm. long, has a similar origin, and likewise fuses at the insertion with the deep surface of the pectoralis major tendon.

This case is of peculiar interest, since it shows the sternalis in combination with frequently-encountered supernumerary pectoral muscles of undoubtedly pannicular origin, and thus suggests the reference of the sternalis itself to the cuticular sheet. The theory of the pannicular derivation of the muscle was first advanced by Prof. Turner, and has found many supporters. The case just described gives the impression that all three of the variants encountered in this subject have a common origin and are to be interpreted as variant derivatives from the pectoral group in the larger sense, *i.e.* that they are to be regarded primarily as persistent portions of the ventro-lateral thoraco-humeral panniculus, and that they appear in turn more or less intimately associated with the subjacent layer of the pectoralis and latissimus by reason of the derivation of the thoracic and axillary cutaneous muscle from the ventro-appendicular system. It is quite evident that all three of the aberrant muscles belong to the same myological plane and are closely associated with each other. In fact, the sternalis and pectoralis quartus are in part directly continuous with each other. Certain general questions raised by this interpretation of the significance of these muscles may be considered under the following heads:—

1. Phylogeny of the panniculus, and its relation to pectoralis and latissimus, in reference to the pannicular derivation of the human variant muscles.
  2. Innervation of the mammalian panniculus.
  3. Innervation of the three variant human muscles here considered.
1. *Phylogeny of the panniculus, and its relation to pectoralis major and latissimus dorsi, in reference to the pannicular derivation of the human variant muscles.*

Comparative myology teaches us that the possession of a more or less extensive and differentiated skin-muscle is a very

widely distributed mammalian character. In the monotremata the ventral portion forms an extensive sheet enveloping the ventral surface of the neck and trunk, and exhibiting connections with the deeper muscles of the anterior limb which will presently deserve our consideration. In other mammalian orders and suborders the muscle appears developed in varying degrees, presenting evidences of extensive reduction in the primates, and especially in man.

A very general disposition of the panniculus in the pectoral and axillary region is well described by Prof. Ambrose Birmingham in his able paper, "On the Homology and Innervation of the Achselbogen and Pectoralis quartus, and the nature of the Lateral Cutaneous Nerve of the Thorax" (*Journ. Anat. and Phys.*, vol. xxiii, p. 214). He says: "In animals we generally find the humeral panniculus as a thin sheet converging from the lateral region of the trunk towards the axilla, where it is inserted in connection with the pectoralis major on its deep surface as a rule; its ventral fibres overlie the great pectoral, the dorsal fibres cover the latissimus, and the intermediate fibres lie against the lateral thoracic wall." This excellent description pictures the panniculus as it is found in a large number of mammalia. In some forms the skin-muscle appears modified and specialized in accordance with special functional requirements, as in certain Rodents (Porcupine) and in *Erinaceus* among the Insectivora, forms in which the development of the protective spines calls a special modification of the cuticular muscle into existence. Mr Parsons, in his valuable contributions to the Myology of the Rodents, has shown that the members of this order offer many instances of a highly-developed and complex cutaneous muscle. In certain forms (Agouti and others) two layers of the panniculus are encountered in the thoracic and humeral region—one superficial to the pectoralis, while the other is placed upon a deeper level and closely associated with the pectoral muscles themselves. The same author<sup>1</sup> in another paper, in fact, suggests that the pectoralis group is derived from the panniculus, and that in reference to the sternalis it is immaterial whether we regard the muscle as part of the panniculus or as part of the pectoralis major. This

<sup>1</sup> *Journ. Anat. and Phys.*, vol. vii., N.S., p. 505, "On the Morphology of the Sternalis Muscle."

intimate association of the panniculus with the pectoral muscular group is very important, and deserves careful consideration in determining the origin of the thoraco-humeral panniculus, and consequently the ultimate source of the human variant muscles which may be regarded as persistent portions of the cuticular muscular sheet. Phylogeny shows us that with the development of the shoulder girdle and anterior limb the primarily metameric disposition of the muscular system follows the lead of the skeletal apparatus and undergoes extensive and far-reaching modifications. Combination of a number of myomeres and the resultant production of individual muscles and muscle-groups, with the concomitant cleavage into layers and the alteration in the direction of the muscular fibres, change the primary simple conditions almost beyond recognition.

The ventro-appendicular muscles, pectoralis and latissimus, gain a relatively enormous surface development and are brought into contact with the integument over a largely-extended area. The development of a pannicular layer from the system of the latissimus and pectoralis is a result of this altered surface relation. I believe that we are justified in regarding the thoraco-humeral panniculus as a derivative from the ventro-appendicular muscular sheet, rather than considering with Mr Parsons<sup>1</sup> the pectoralis as a product of the panniculus.

The connection between pectoralis and panniculus is still to be traced in the monotremata, in which forms a considerable segment of the anterior ventral panniculus is derived from the humeral insertion of the pectoralis. The massive cuticular muscle of the American Manatee enters into extensive combination with the pectoralis and latissimus and with the musculature of the paddle. In birds a number of the deeper muscles—(Trapezius, Deltoid, Pectoralis, Serratus, Latissimus, etc.)—furnish muscular bundles which find their insertions in the patagium as tensors of this membrane. In mammalia in general the direct derivation of the ventral thoracic panniculus from the subjacent ventro-appendicular muscles is not so evident in all instances; and yet in many forms—as in the rodents examined by Mr Parsons—the connection between

<sup>1</sup> *Loc. cit.*, p. 507.

the two is well exemplified. As a matter of fact, it is not difficult within a comparatively limited number of types to illustrate a series of successive stages between the imperfectly segmented panniculus—still extensively united with the pectoralis—and the entirely free cuticular muscle. I believe that we are justified in regarding the panniculus and pectoralis as phylogenetically very closely connected structures; and in considering the former as a differentiated product of the superficial ventro-appendicular muscular group, which becomes variously modified—specially developed in some forms—while in others it appears greatly reduced—according to the demands of functional requirements in different animals. It is rational to regard the modifications of the muscular system resulting from the development of the pectoral girdle and anterior extremity as primary alterations of the metameric muscular type, and to consider the cuticular muscle as a further and secondary derivative of the appendicular muscular group, rather than to accept the panniculus as the primary structure from which the appendicular muscles are to be derived. This view of the mutual relationship of the muscular layers in question greatly simplifies the problems of innervation which are encountered.

The derivation of the variant human muscles forming the subject of this communication from the panniculus has been advocated by a number of authors. Sir William Turner<sup>1</sup> considered the sternalis as a remnant of the cuticular muscle, and his view has found many able supporters. Prof. Birmingham, in the paper quoted, proves conclusively that the axillary arch is a pannicular derivative. As regards the pectoralis quartus, he considers the muscle “a segmented portion of the great pectoral” (*loc. cit.*, p. 223), and denies its possible connection with the panniculus on the ground of *position*, basing his belief (1) on the conditions encountered in the kangaroo and wallaby, where the “pectoralis quartus is very large, its ventral fibres blend with the pectoralis major, and its dorsal fibres with the latissimus dorsi, while it is covered superficially by the panniculus”; (2) on two cases of Dr Brooks’ in which the axillary arch was attached to the pectoralis quartus instead of

<sup>1</sup> *Journ. Anat. and Phys.*, vol. i., p. 246.

to the lower border of the great pectoral—"here the quartus evidently took the place of part of the major"; (3) on the condition found in the cat, in which animal Prof. Birmingham finds the panniculus closely connected to the axillary borders of the pectoralis and latissimus. With care, however, it is possible to separate the panniculus from the underlying muscles, when the interval is seen to be very narrow, pectoralis and latissimus actually touching in one place. "In this narrow interval, and under cover of the adjacent part of the pectoralis major to a considerable extent, we find the pectoralis quartus, while the panniculus covers the interval and its contained muscle completely."

All these conditions appear to me capable of reconciliation with the derivation of the quartus from the panniculus if we keep in mind the *origin* of the cuticular muscle. The instances cited by Prof. Birmingham illustrate the same facts which the panniculus of the rodents demonstrates, namely that the panniculus is frequently encountered in two layers—a superficial portion corresponding in position to the human platysma, and a deeper stratum more intimately connected with the pectoralis. Regarding the entire skin muscle as a derivative from the ventro-appendicular sheet, it is not surprising to find examples in which the segmentation is, so to speak, incomplete, and in which, beneath a superficial free cuticular muscle, a portion of the same system, in process of separation from the parent ventro-appendicular layer, is encountered. In fact the pectoralis quartus, of the three variant human muscles here considered, is the one most prone to bear the evidences of its derivation from the pectoral division of the limb muscles. Again, the connection of the axillary arch with the latissimus can probably be regarded as representing the opposite condition, viz., a secondary fusion or reunion of a portion of the formerly free panniculus with the layer from which it was originally derived. Instead of considering panniculus and pectoralis as morphologically distinct units, a correct estimation of their relationship will reconcile the view which regards the pectoralis quartus as "a segmented portion of the great pectoral" with that which holds the muscle to be a deeper part of the panniculus, in the majority of instances *not yet* completely differentiated from

the pectoralis major. That the axillary arch, which Prof. Birmingham and others have conclusively shown to be derived from the panniculus and the pectoralis quartus, are parts of the same system is suggested by the very cases of Dr Brooks' above quoted, and by the specimen here under consideration. I have likewise records of seven additional instances in which the axillary arch and pectoralis quartus united in the axilla, and similar conditions have been recorded by Prof. Humphry and others.

We may sum up the facts concerning the pectoralis quartus by saying that it appears as a derivative of the panniculus; that its lateral termination is more prone to exhibit complete pannicular character, as evidenced by its frequent union with the arch, an unquestioned cuticular derivative; that its mesal attachment preserves in many instances the connection with the pectoralis major more or less completely; that, in other words, the muscle is apt to represent an incomplete stage of that differentiation from the ventro-appendicular muscle which we must regard as the final step in the production of the general panniculus.

## 2. *Innervation of the panniculus.*

Mr Parsons finds that the ventral panniculus in *Dasyprocta* and other rodents examined by him is supplied by a large nerve, which also innervates the pectoralis, and which he identifies with the human internal anterior thoracic nerve.

Prof. Wilson<sup>1</sup> has shown that the panniculus generally receives its supply from "the lateral cutaneous nerve of the thorax," and Prof. Birmingham (*loc. cit.*) proves that this nerve is the homologue of the human lesser internal cutaneous, associated with another element representing a portion of the internal anterior thoracic nerve, which is usually absent in man, but appears as the nerve of the axillary arch when that muscle develops.

The nerve supply, therefore, confirms the derivation of the

<sup>1</sup> J. T. Wilson, "The Innervation of Axillary Muscular Arches in Man, with remarks on their Homology," *Journ. Anat. and Phys.*, N.S. vol. ii., p. 294; "Further Observations on the Innervation of Axillary Muscles in Man," *Journ. Anat. and Phys.*, N.S. vol. iv., p. 52.

panniculus from the pectoral group, and affords conclusive evidence of the close morphological relationship between the two.

3. *Innervation of the three human variant muscles here considered.*

(a) *Pectoralis quartus*.—Both Prof. Birmingham and Prof. Wilson find the nerve of this muscle derived from the internal anterior thoracic nerve.

(b) *Axillary arch*.—The same observers have determined that the nerve supply of the axillary arch is also derived from the anterior thoracic trunks.

(c) *Sternalis*.—As above stated, modern investigations practically prove the anterior thoracic nerve supply of this muscle.

*Conclusions regarding the possible interpretation of the sternalis as a reversional pannicular muscle.*

1. The innervation of the sternalis demonstrates the variant to be either

(a) a portion of the pectoral mass in the narrow meaning, *i.e.* a displaced and a typical segment of the pectoralis major in Cunningham's and Eisler's sense; or

(b) a persistent reversional remnant of a portion of the superficial thoracic pannicular sheet, originally derived from the pectoralis, but normally not developed in man.

2. The innervation, therefore, not only indicates the close association of the sternalis with the pectoral muscle in the broadest meaning of the term, but it also correlates the same with the other superficial variant muscles of pectoral derivation and assembles them into a group, united both by the mutual relations of the individual components and by the common origin from the parent layer of the pectoralis.

3. Reference of the sternalis directly to the pannicular muscle is therefore not incompatible with either the innervation or the phylogenetic history of the cuticular layer, and, provisionally at least, this possible character of the variant should be considered in drawing general conclusions regarding the derivation and significance of the sternalis.



4. In estimating, however, the value of the etiological factors concerned in its production, it is evident that many cases of the muscle are to be referred directly to the pectoralis major, without pannicular intervention, as atypically displaced portions of this muscle in correspondence with the ontogenetic causes above defined.

5. The inference lies at hand that the types of the muscle belonging to Group B, and suggesting, either in their structure or in their association with other coexisting pectoral variants, pannicular derivation, are more properly to be regarded as less pronounced instances of the same displacement, involving merely such limited portions of the parent muscle that the gross conformation of the same does not suffer from this abstraction of a small segment, and that hence it presents a normal appearance.

6. It is, of course, conceivable that the general etiological factors previously considered should in individual cases become operative in conjunction with partial reversional appearance of a pannicular remnant. This interpretation might be assigned to instances in which the sternalis appears in combination with evidently pannicular supernumerary muscles, as in the above-described case of a sternalis in conjunction with the axillary arch and the pectoralis quartus.

7. On the other hand, these conditions may be regarded as examples of what we may, for want of a better term, call the "Variation diathesis," a strong tendency toward atypical or reversional formation affecting the entire muscular system in certain individuals, and producing multiple aberrant and supernumerary muscles in a single subject.

This view is sustained by the occasional observation of cases in which the sternalis occurs in combination with muscular variants of the thoracic region entirely outside of the pectoral sphere. Thus Prof. Ferris, of New Haven, recently communicated to me the records of an observation in which, with a well-developed bilateral sternalis, a typical supra-costalis was found on the left side. In this instance we are dealing with two muscular variations of the same topographical region in the same subject, one derived from the system of the pectoralis, the other associated with the sheet of the scalenus and external

oblique. They are hence entirely independent of each other, and their simultaneous appearance in the same individual must be regarded as a coincidence, warranting perhaps the somewhat vague assumption that in cases of this kind a general, possibly hereditary, tendency to atypical development of the muscular system exists.

8. Again, the instances of sternalis occurring in combination with other variant muscles of direct pectoral origin deserve especial consideration in this connection. The most available instance of this is the case reported by Dr Bryce,<sup>1</sup> and already discussed in relation to the deep or intermediate group of pectoral variants. In this case the reverse of the conditions seen in Pl. XI. fig. 2 were found, namely, the direct continuity of the sternalis with the sterno-clavicularis, a variant derived, as above suggested, by atypical development directly from the plane of the pectoralis major, and not of pannicular character. Here we find direct union of a distinct pectoral element with the sternalis, and in this sense the case corresponds to the more frequently observed continuation of portion of a sternalis into the superficial layer of an otherwise normal pectoralis major. Its importance for our present inquiry lies, however, in the fact that it bridges the interval between the sternalis conjoined with additional variant muscles of *pannicular* origin, as seen in Pl. XI. fig. 2, and the occurrence of the sternalis as a solitary variant with or without defect in the sheet of the pectoralis major. In other words, the sternalis can appear either alone, or in combination with superficial aberrant muscles, or with deeper variants. In Dr Bryce's case the muscle is conjoined with the sterno-clavicularis, and there is coexisting atypical development and partial deficiency of the pectoralis major. The inference lies at hand to associate the abnormal form of the pectoralis not only with the sterno-clavicularis, but also with the sternalis, and thus to lead directly to the correlated group of isolated sternales, with derangement of the pectoral musculature, but without additional supernumerary muscles. In the same sense the case recorded and figured here (Pl. XI. fig. 2) may be taken as an example of those conditions in which, without gross disarrangement of the pectoral muscula-

<sup>1</sup> *Loc. cit.*

ture, supernumerary elements appear as the result of slighter disturbances in the normal processes of pectoral development. These processes usually lead to the production of the solitary sternalis with underlying normal pectoralis, but in this instance, either by themselves or in association with the rever-sional appearance of pannicular rudiments, have led to the combination of muscular elements above noted.

9. It may therefore be concluded that the weight of evidence is *against* the assumption of a direct pannicular origin of the sternalis. No matter how varied the form, volume, attachments, relations, etc., of the muscle may be, all types of the structure can be satisfactorily united on the basis of direct derivation from the pectoralis sheet *sensu stricto*.

*Group C.*—The third group of sternales, in which the direct or indirect connection with the pectoralis major forms the distinctive morphological character, is, of course, readily co-ordinated with the preceding subdivisions, as examples of the variant in which, under the influence of identical etiological factors, the separation from the parent layer of the pectoralis major has not attained the complete degree characterizing the other types. Naturally a wide range of minor individual variation is here offered, and the development of the muscle may be to a marked degree irregular.

*General conclusions regarding the derivation, morphological significance, and etiology of the sternalis.*

1. Basing our conclusions on the facts of structure and inner-  
vation above outlined, we are justified in accepting the sternalis in its extensive range of individual and specialized forms as a product of atypical development of the pectoral mass in the wider sense.

2. Two general and fairly well-defined groups can be distinguished to which individual instances of the muscle can be more or less definitely assigned:

*A.* Sternales, occurring usually as well-developed muscular bands, associated with marked disturbances in the typical development of the pectoralis major, and accompanied by more or less actual deficiency in the corresponding segment of the sterno-costal division of the muscle. In these instances the

abnormal muscle is clearly an atypical and displaced segment of the pectoralis major, whose connections with adjacent structures, as the frequent union with the sternal head of the sternocleido-mastoid, are secondarily acquired and morphologically unimportant characters.

*B.* A second general group of sternales is characterized by the slender and delicate form of the aberrant muscle, while the underlying pectoralis major appears in every respect normal.

Two possibilities suggest themselves in considering the derivation of this type:

*A.* Regarding the sternalis still as a displaced portion of the pectoralis major, it can be assumed that the rotated and atypical segment forms so slight a part of the entire pectoral mass that its loss and diversion from the same leaves no visible deficiency, and produces no disturbances in the typical development of the main muscles. This view is quite compatible with the known facts in the development of the pectoralis, which may be held responsible for the production of atypical derivatives.

*B.* A certain number of sternales suggest a derivation directly from abnormal persistent portions of a thoracic panniculus. The latter being in turn originally derived from the pectoral mass, the origin of the variant muscle is therefore again the pectoralis, although the derivation is less direct than in first group of displaced and rotated pectoral segments, occurring through the intervention of a pannicular antecedent.

This view is supported by the occasionally-observed instances of a sternalis occurring in direct continuity with other abnormal pectoral muscles which are both phylogenetically and by their innervation characterized as direct derivatives from the panniculus. In these cases the sternalis may possibly represent a reversion of part of the cuticular muscle. More probably, however, they are to be interpreted as examples of *coincidence* of several etiological factors simultaneously operative in the same individual, and leading to the production of several co-existing variants, of which the sternalis is to be regarded as produced by the same forces responsible for the development of the muscle in uncomplicated cases, while the others, such as the axillary arch and pectoralis quartus in the instance above described, represent pannicular reversions.

3. *Relation between the sternalis and the deep supernumerary pectoral muscles.*—We have, as previously seen in other portions of the pectoralis major, departures from the normal type of development leading to the production of deeper supernumerary muscles which represent clearly atypical and displaced pectoral segments, as the tensor semivaginæ, M. chondro-coracoideus ventralis, M. præ-clavicularis. This congruence of structural character in relation to the pectoralis plane strongly suggests the propriety of uniting the superficial and intermediate pectoral variants morphologically and genetically into a common general group, and this view is borne out by the cases, such as the one recorded by Dr Bryce, in which representatives of both the superficial and deeper division of muscular variants occur in the same individual, apparently in response to identical general causes leading to disturbances in the normal development of the pectoral musculature. In the usual cases, however, we find, contrasted with the deep position of the intermediate muscles, and requiring explanation based on the agency of secondary determining causes, the fact of the uniformly superficial ventral position of the sternalis, and of the graded series of stages by which the muscle in different individual instances passes from the massive muscular band with correspondingly deep deficiency of the pectoralis to the thin superficial ribbon with extensive fascial connections which leaves the underlying main muscle to all appearances normal and undisturbed.

4. *Etiology of the sternalis.*—The various questions raised by these considerations of the sternalis regarding the influences leading to the production of the variation as an atypical segment of the pectoralis major, and the modifying secondary conditions responsible for the appearance of the various types assumed by the muscle, find their explanation in the developmental history of both the pectoral musculature, and probably the ventral thoracic wall.

5. The preponderance of the sternalis in ancephaly is apparently due to mechanical conditions favouring disturbances in the normal migration of the embryonic pro-pectoral mass, and coincidentally leading to atypical structure of the interchondral spaces. At the present writing the evidence seems to point to ancephaly as being responsible for *both* atypical muscular

development leading to the production of the sternalis and to asymmetry in the structure of the ventral thoracic walls.

The direct dependence of the muscular variation upon the latter condition, in Eisler's sense, is not apparent from the material so far available, and the observations at hand suggest that both anomalous conditions may, provisionally at least, be referred to the same etiological factors. They therefore appear frequently *coincident* with each other in the same individual, or may develop independently of each other.

6. The skeletal, fascial and muscular connections of the sternalis are, in the majority of cases, *secondary* acquisitions, such as the commonly-encountered junction of the cephalic extremity with the sternal tendon of the sterno-cleido-mastoid, and distally the connection with the aponeurosis of the external oblique, or the lower true ribs and cartilages. These connections are of little or no value in determining the significance of the variant or the muscular group to which it should be assigned. On the other hand, their early acquisition, preceding or during the embryonic migration of the pro-pectoral muscular mass, may very well be considered as one of the secondary factors determining the extent and character of atypical pectoral development leading to the various forms assumed by the sternalis.

7. Occurrence of the sternalis in combination or even direct continuity with certain other abnormal or supernumerary muscles of the pectoral region.

Three conditions are to be distinguished here :

(a) Sternalis, combined with deficiency of the pectoralis major, and with one or more of the deep group of supernumerary muscles above considered, as in the case reported by Dr Bryce.

These instances are to be interpreted in the same sense as the uncomplicated cases of sternalis described above under Group A. The disturbance of the normal type of development of the pectoral musculature is here more extensive and far-reaching in its results, leading to the production of both the superficial variant (sternalis) and one or more of the deeper intermediate group.

(b) Sternalis, combined with one or more superficial supernumerary muscles of pannicular origin, as the pectoralis quartus and axillary arch in the case above reported.

The evident pannicular derivation of the other aberrant muscles might suggest the possibility of a similar origin for the sternalis, the muscle then representing an *indirect* derivative from the pectoralis sheet, instead of—as in the first case—a *directly* displaced segment of the normal pectoralis major. More probably, however, these instances are to be interpreted as examples of coincidence in the same individual of atypical muscular structures, derived from the same morphological plane, but due immediately to a combination of etiological factors simultaneously operative.

(c) This is certainly the explanation of the third group, in which the sternalis occurs in combination with other aberrant thoracic muscles, not connected with the pectoralis. Thus in Dr Ferris' instance, where a double sternalis occurred in combination with a typical supra-costalis. Here a pectoral variant is associated with one belonging to the system of the scalenus and external oblique, and the case may be regarded as an example of what we may term a "Variation-diathesis," as so frequently observed in individuals with multiple muscular anomalies. These conclusions may be summed up in tabulated form as follows:—

### SUMMARY.

I. DERIVATION AND SIGNIFICANCE.—Plane of pectoralis major, as shown .

A. By the innervation through branches of the anterior thoracic nerves.

B. By the relations of the sternalis to its myological and skeletal environment.

Derivation from superficial pectoral layer in the majority of cases *direct*. A few instances of combination of sternalis with other supernumerary muscles of pannicular origin suggest possible phylogenetic *indirect* derivation of sternalis from pectoral mass, as reversional remnants of thoraco-humeral cutaneous muscle. More probably these cases represent *coincidence* of occurrence of multiple variations from several sources, the sternalis still *directly* pectoral in derivation, the

associated variants *indirectly* derived from the same system through the panniculus.

II. MORPHOLOGY.—Three general groups :

1. Sternalis with underlying normal pectoralis major.
2. Sternalis with coexisting deficiency and abnormal construction of pectoralis sheet.

3. Sternalis, combined with, or in direct continuity with, other muscular variants of the pectoral region, with or without coincident atypical development of pectoralis major.

A. With variants representing clearly misplaced portions of pectoralis major—Bryce's case. (Identical etiological factors affecting large area of pectoralis produce not only sternalis but additional variants of identical derivation.)

B. With superficial supernumerary pectoral muscles of unquestionably pannicular origin—Huntington's case. (Combination of various etiological factors of the same myological district leads to simultaneous development of sternalis from pectoral sheet, and other variants from remnants of the panniculus.)

C. With muscular variations of the thoracic region other than those derived from the pectoralis system—Ferris' case. (Atypical muscular diathesis leading to occurrence of multiple non-related myological variants.)

III. ETIOLOGY.

1. Ontogenetic pectoral migration.

2. Preceding or coincident atypical secondary muscular or skeletal connections leading to diversion of part of superficial pectoral layer to form the sternalis, and responsible for the minor variations presented by the muscle.

3. Closure of midsternal fissure as influencing atypical disposition of superficial pectoral elements during ontogenetic descent.

II. M. INFRA-CLAVICULARIS.

Supernumerary pectoral muscles, other than the sternalis, ventrad of the pectoralis major, are of comparatively rare occurrence. They belong to the same general morphological group as the variants previously discussed, and represent atypically diverted portions of the superficial pectoral lamina,



usually derived from the clavicular head, and hence extending from the clavicle in varying degrees caudo-laterad over the subjacent pectoralis and deltoid. In their complete development they appear as the *M. infra-clavicularis*, a well-marked example of which is shown in Pl. XIV. A strong flattened muscular belly, arising from the mesal third of the ventral surface of the clavicle, extends laterad to terminate in a broad and firm fascial expansion covering the superficial aspect of the deltoid. There is no deficiency of the pectoralis major, but the delto-pectoral cleft, bridged by the aberrant muscle, is very distinct.

*Innervation*.—A branch of the external anterior thoracic nerve passing around the cephalic border of the pectoralis major enters the muscle on its deep surface near the middle.

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#### EXPLANATION OF PLATES.

Pl. I. Columbia University Museum, No. 2533. Adult human subject. Left pectoral region with *tensor semi-vaginæ*.

Pl. II. From a fresh dissection. Adult human subject. Right pectoral region with *tensor semi-vaginæ* (intermediate ento-pectoral slip).

Pl. III. Columbia University, Study Collection. Adult human subject. Dissection of pectoral region, with bilateral *tensor semi-vaginæ* and extensive deficiency of pectoralis major.

Pl. IV. Columbia University Museum, No. 2334. Adult human subject. Right pectoral region with *tensor semi-vaginæ*.

Pl. V. Columbia University, Study Collection. *Putorius vison*, Mink. Dissection of pectoral region.

Pl. VI. Columbia University, Study Collection. *Cercoleptes caudivolvulus*, Kinkajou. Dissection of pectoral region.

Pl. VII. Columbia University Museum, No 2389. Adult human subject. Left pectoral region with *tensor semi-vaginæ* and *sterno-chondro-coracoideus ventralis*.

Pl. VIII. fig 1. Columbia University, Study Collection. Human fœtus near term. Pectoral region with *sterno-clavicularis* and *sterno-scapularis*.

Pl. VIII. fig. 2. Same specimen, with pectoralis major reflected on right side.

Pl. IX. Schematic representation of mutual relation existing between the members of the deep group of supernumerary pectoral muscles.

Pl. X. From a fresh dissection. Adult human subject. Right pectoral region, with *sternalis* and extensive deficiency of *pectoralis major*.

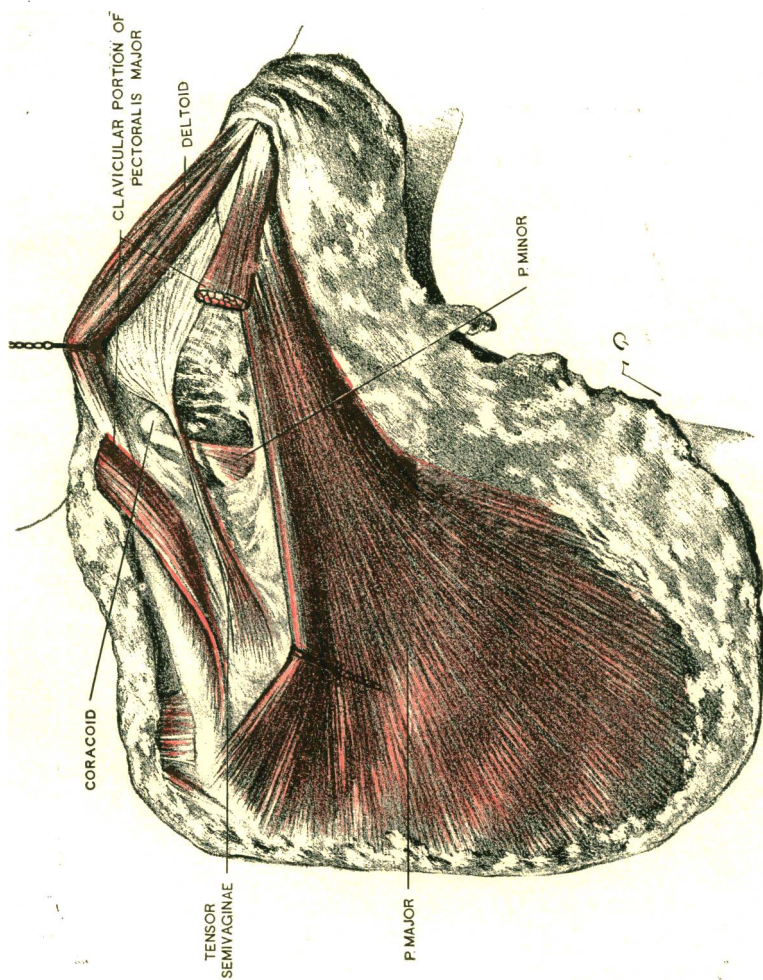
Pl. XI. fig. 1. Columbia University Museum, No. 935. Ancephalic foetus. Pectoral region with bilateral *sternalis* and right superficial lamina of *pectoralis major*.

Pl. XI. fig. 2. Columbia University, Study Collection. Adult human subject. Pectoral region with *sternalis*, *pectoralis quartus* and *axillary arch*.

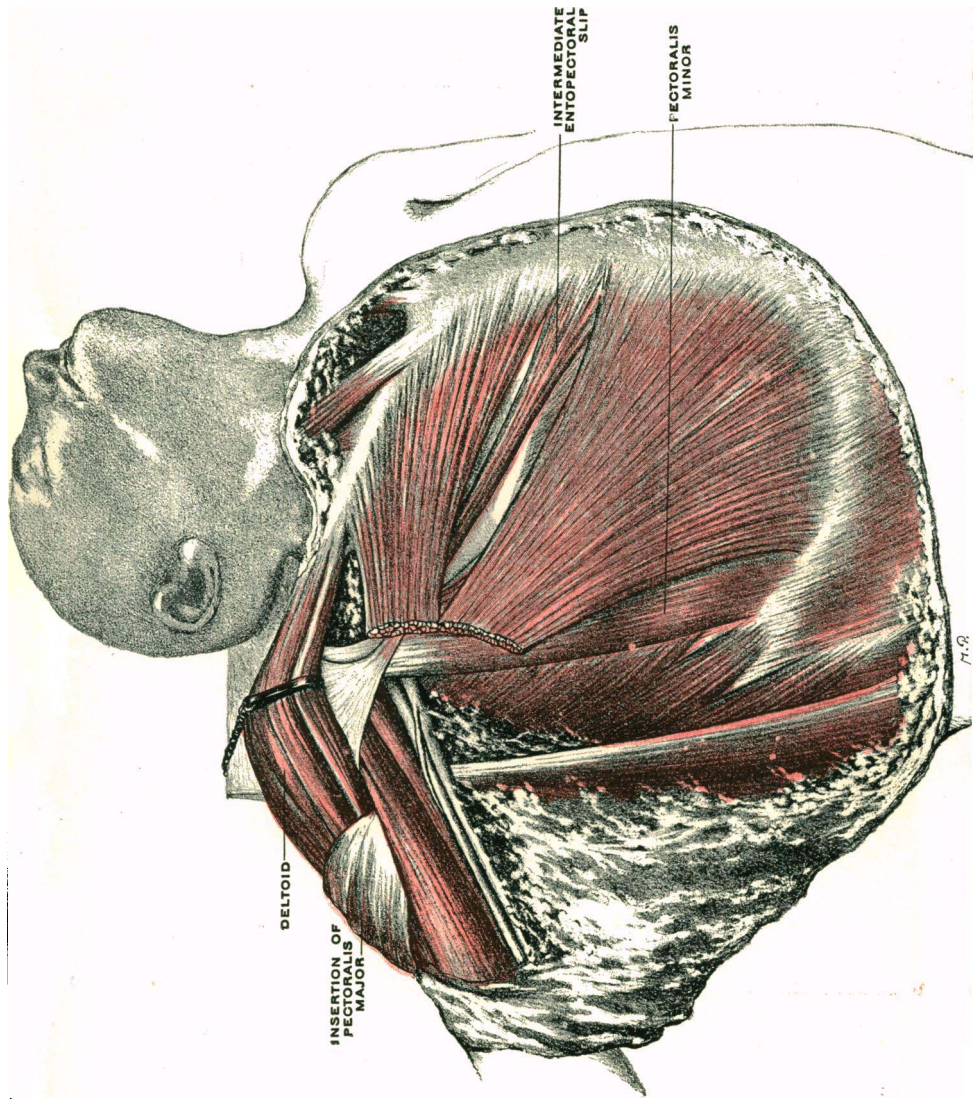
Pl. XII. From a fresh dissection. Ventral thoracic wall of subject shown in Pl. X. denuded of the pectoral musculature to exhibit sternum and formation of interchondral spaces.

Pl. XIII. Columbia University Museum, No. 2218. Sternum and costal cartilages of same subject, macerated.

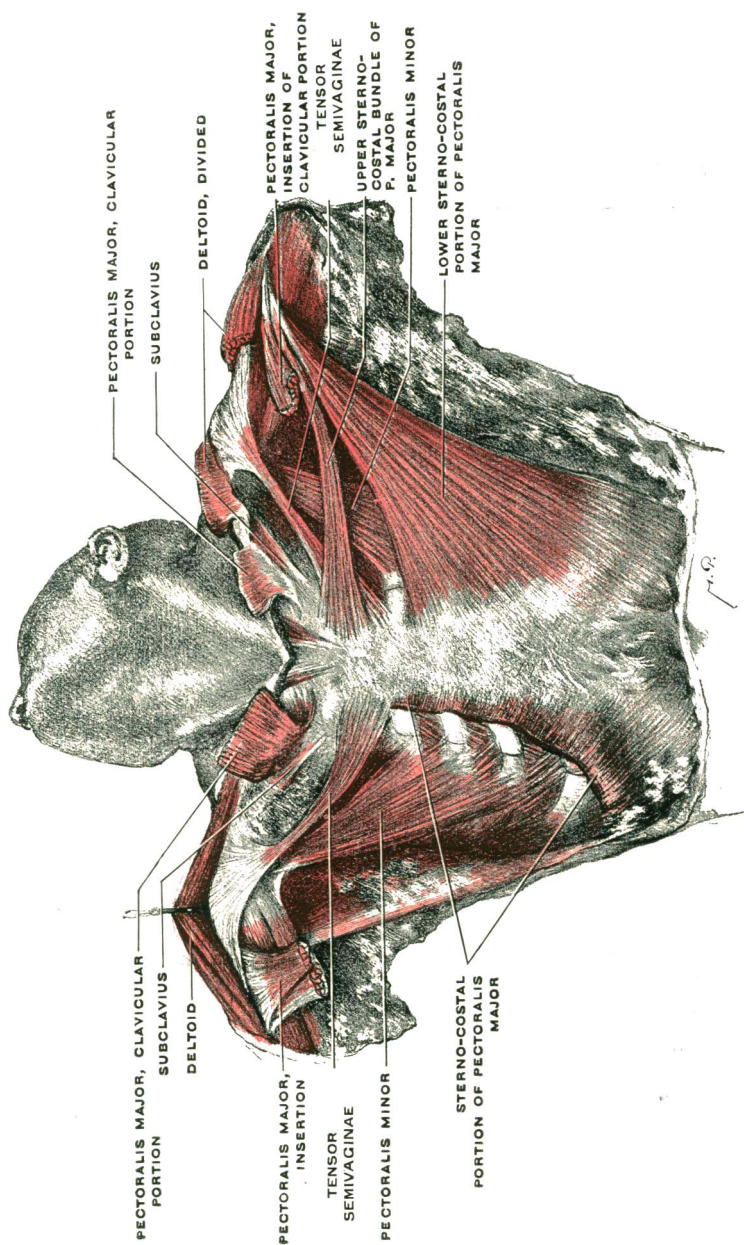
Pl. XIV. Columbia University Museum, No. 2514. Adult human subject. Left pectoral region with *infra-clavicularis*.



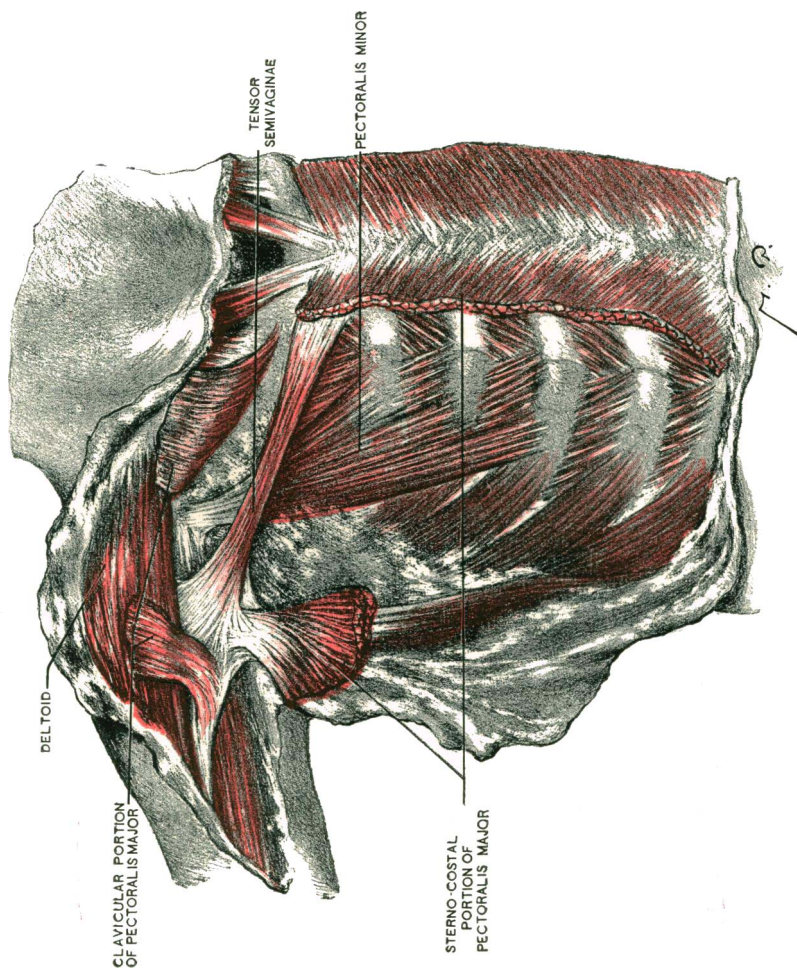
Dr. GEO. S. HUNTINGTON.

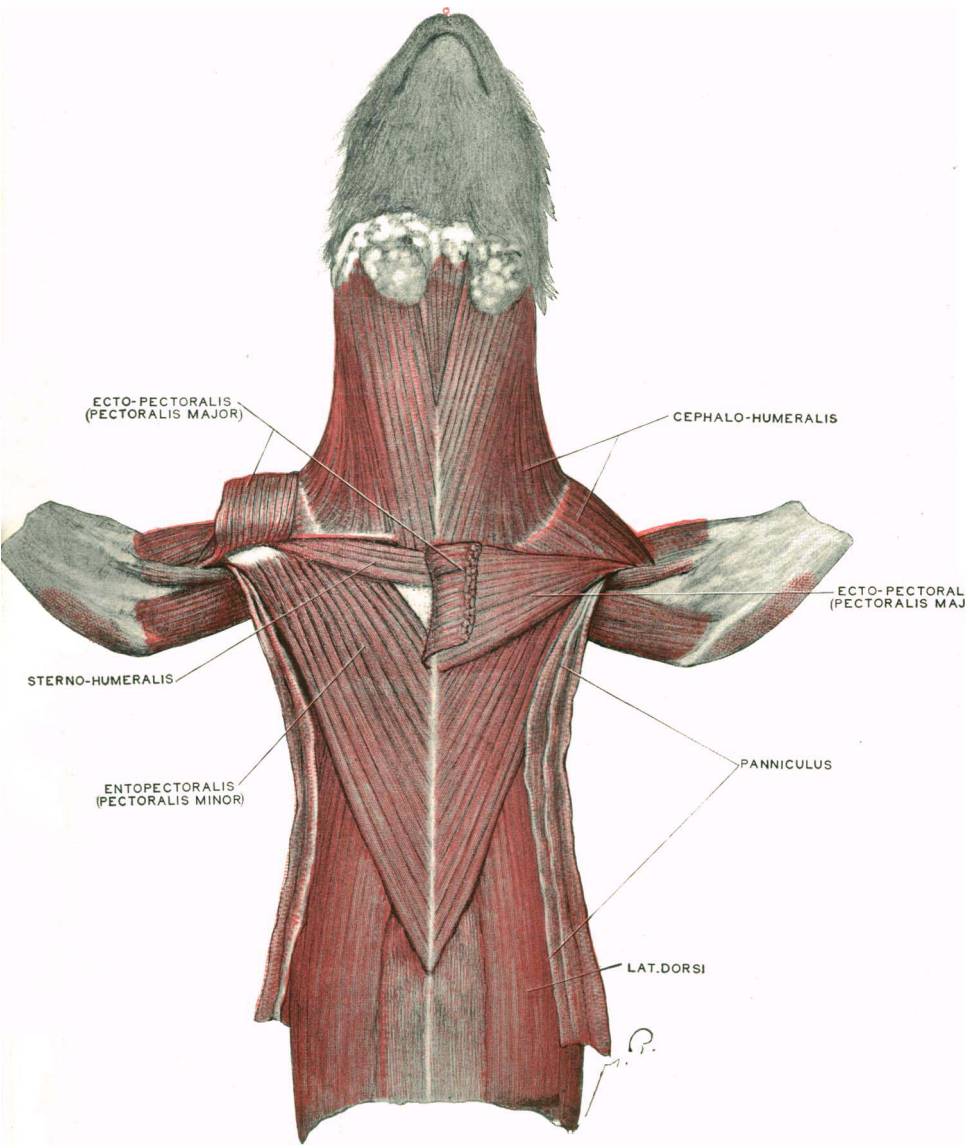


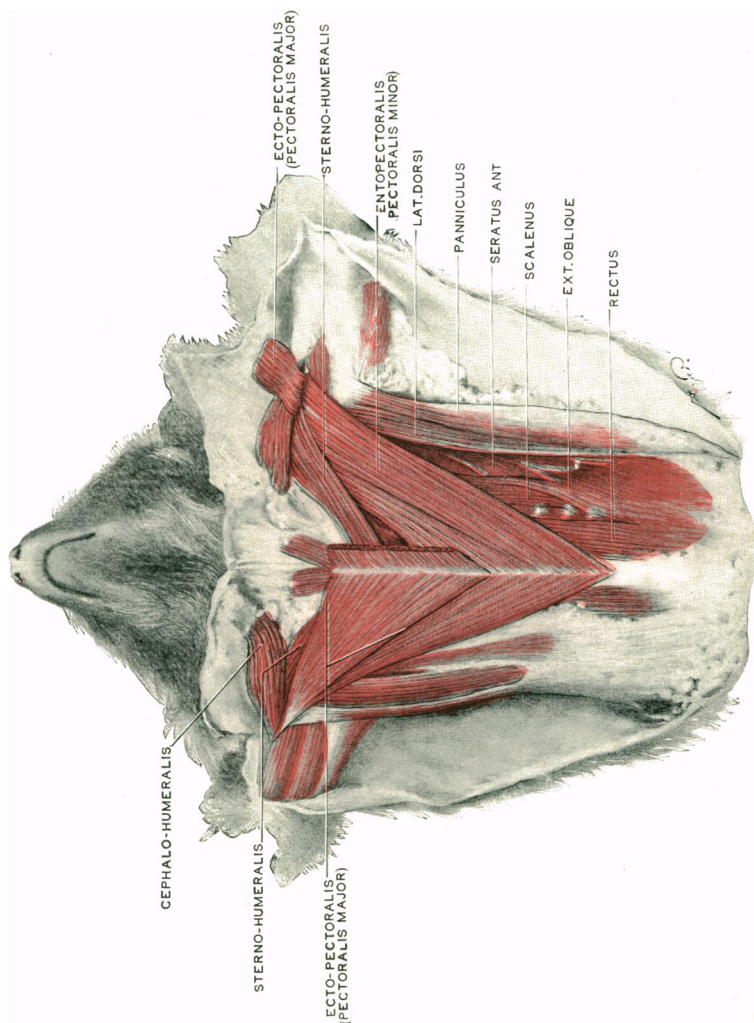




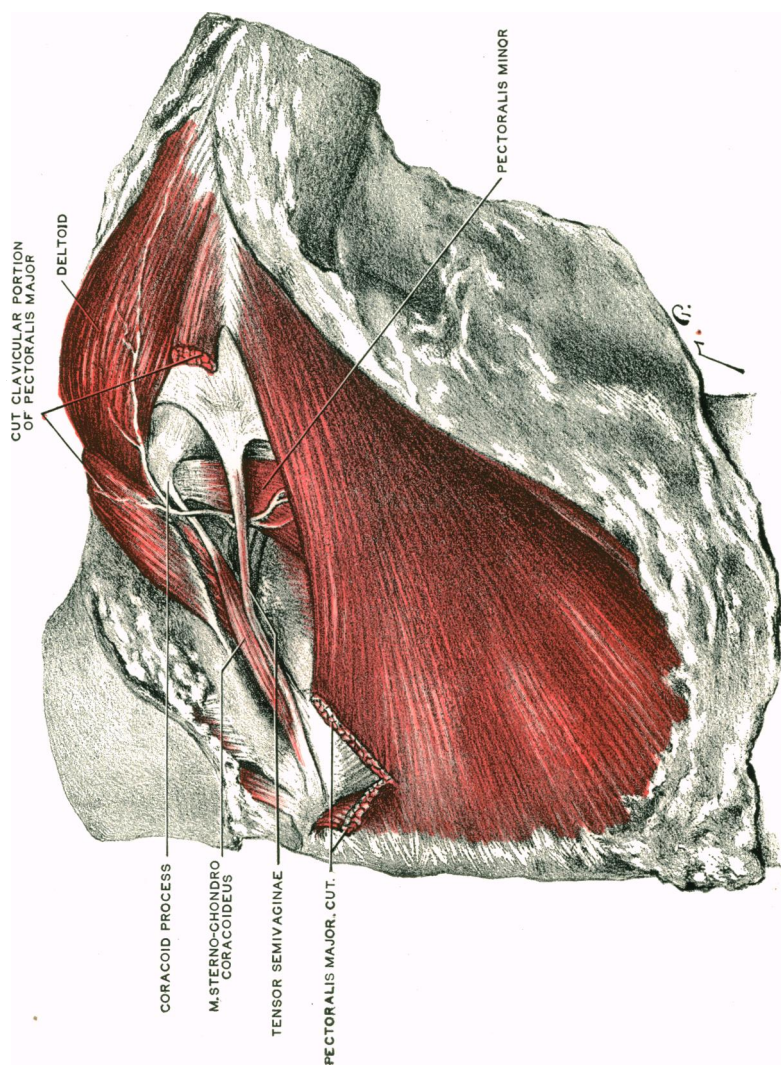
Dr. Geo. S. Huntington.











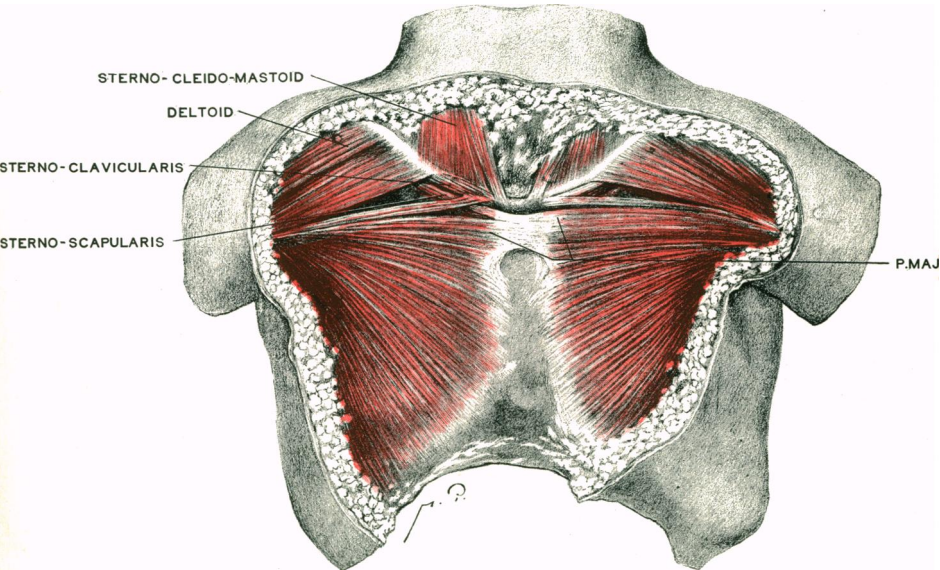


FIG. 1.

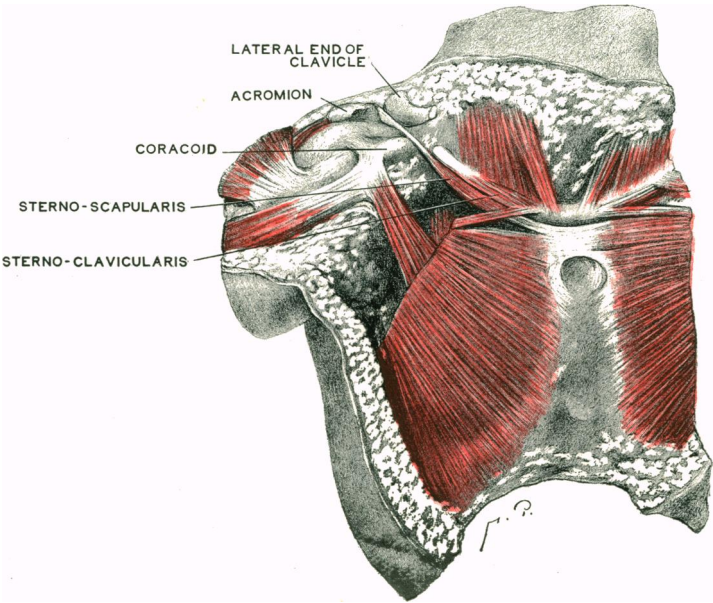
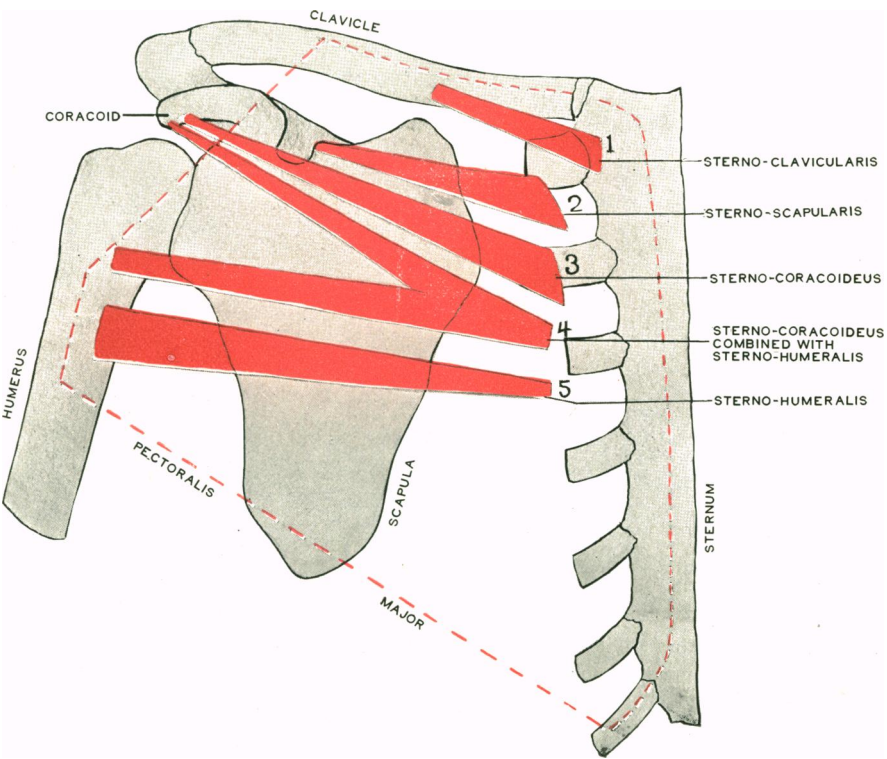
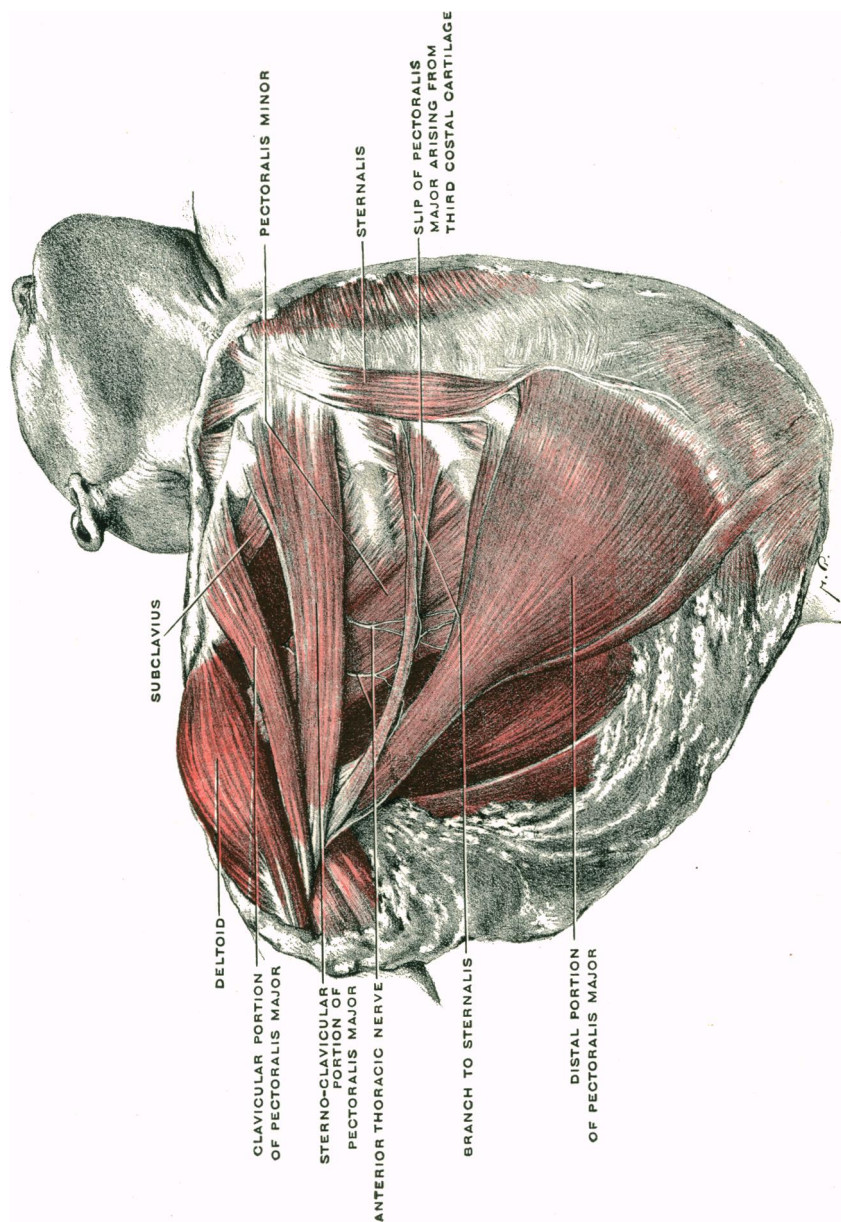


FIG. 2.







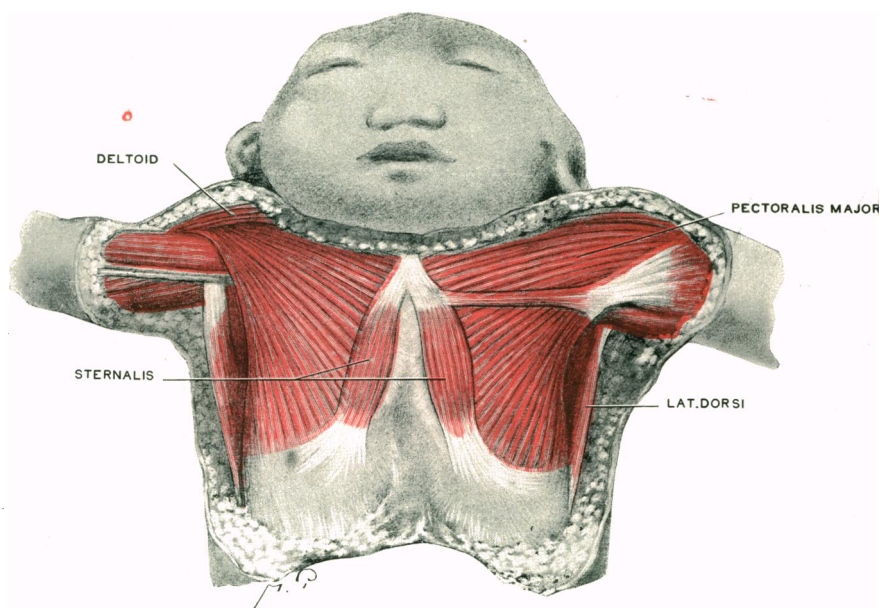


FIG. 1.

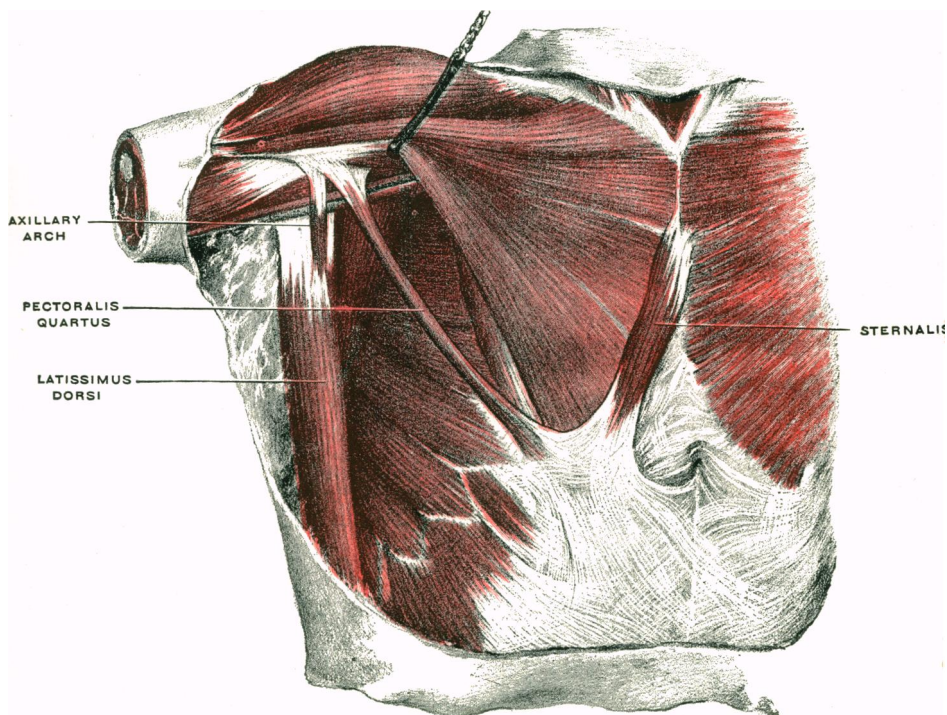


FIG. 2.

